AN INVITING TRAIL IN NATURE

DYNAMIC BIOLOGY

By

ARTHUR O. BAKER

Directing Supervisor of Science
Cleveland Public Schools

LEWIS H. MILLS

Principal, Kennard Junior High School
Cleveland Public Schools

Edited by

WILLIAM L. CONNOR

Superintendent of Schools, Allentown, Pennsylvania
Formerly Chief, Bureau of Educational Research
Cleveland Public Schools

Drawings by
EARL WOLF

RAND McNALLY & COMPANY

NEW YORK CHICAGO SAN FRANCISCO

PRINTED IN U.S.A.

Made in U. S. A.

1-45

H-45

TABLE OF CONTENTS

The materials of this book are organized into large controlling units. Since each unit is complete in itself, the order of presentation may be changed if the teacher desires. The authors, however, have found the order as given here very satisfactory.

UNIT SEVEN. EXPLORING THE PLANT AND ANIMAL GROUPS

UNIT EIGHT. ON NATURE'S TRAILS

UNIT NINE. HOW LIFE FORMS DEPEND UPON ONE ANOTHER

UNIT TEN. HOW PLANTS AND ANIMALS BEHAVE

UNIT ELEVEN. REPLENISHING THE WORLD WITH LIFE

UNIT TWELVE. FROM FERTILIZED EGG CELLS TO INDEPENDENT ORGANISMS

UNIT THIRTEEN. THE LAWS OF HEREDITY AND THE IMPROVEMENT OF MANKIND

UNIT FOURTEEN. CHANGING FORMS OF LIVING THINGS

PREFACE

We are living in a new day in American education—a day when we give more study to the real purposes of education and to the real nature of learning. The concept of learning may be summarized in the following statement:

> Modern education is characterized by the notion that learning is the active reaction of the whole organism of the learner to a dynamic environment.

In harmony with this fundamental concept, the content of *Dynamic Biology* has been selected and organized according to the interests, needs, and abilities of students themselves. Moreover, it has been selected and organized according to certain dynamic processes of learning that have been found effective in carefully controlled experiments. Thus it accomplishes the following broad purposes with reference to individual and social welfare:

1. It yields a basis for the development of desirable attitudes and standards, and consequently for a wholesome outlook on life.
2. It helps the student to acquire scientific methods of procedure.
3. It provides a fundamental knowledge of life processes.
4. It supplies a background for an intelligent solution of various problems that arise in the home and community.
5. It provides a reliable basis for the development of standards of healthful living.
6. It offers opportunities for the development of recreational activities and hobbies, particularly the study of interesting forms of life in the immediate environment.
7. It presents numerous situations helpful in arriving at vocational conclusions.
8. It develops a wholesome respect for men who have made notable contributions in the field of biological research.

The content of biology is of vital importance. The problem in a high-school textbook is to present this content in such a way that the student will be attracted and consequently come to realize its real significance. Above everything else, then, the content must be interesting. The content of *Dynamic Biology* is interesting (1) because it is closely related to the student's own experiences, and (2) because it is dynamic—that is, stimulating to further study and to action. As part of the dynamic feature the content contains many dramatic incidents. Unit One, for example, begins with a fact of nature commonly observed even in large cities—the migration of waterfowl. A most unusual feature of this migration, however, is emphasized—myriads of birds using artificial resting and feeding grounds provided by the insight and energy of a public-spirited man.

The content of *Dynamic Biology* fully satisfies the provisions of state and city courses of study and the technical requirements for college entrance. At the same time, it satisfies the interests and needs of students who cannot continue their training beyond the high school. Each unit includes the subject matter related to a major aspect of biology. The sequence of units provides a psychological organization of materials, but the teacher may readily modify the order to meet special conditions. For example, he may teach Unit Five, "Friends and Foes among the Insects," early in the fall when he can secure specimens most easily, or Unit Eight, "On Nature's Trails," in the late spring when he can make outdoor activities most pleasant. He will experience little or no difficulty in changing the order, for each unit is complete in itself. All technical terms within the unit are defined and often pronounced at the first point of use. Thus in no sense does one unit depend upon another for explanatory materials. The authors recommend, however, regardless of the order in which the units are taught, that Units Seven and Fourteen, "Exploring the Plant and Animal Groups" and "Changing Forms of Living Things," be used in large part as summaries, respectively, of the first and second halves of the book.

Each unit begins with a stimulating preview which serves to orient the student into the work that is to follow. Following the preview is a list of all the problems to be considered in the unit. The sequence of the problems provides a progressive development of subject matter. At the end of each unit are summarizing activities to guide the student (1) in checking his understanding of the unit; (2) in organizing and applying his knowledge; and (3) in carrying on further activities according to individual interests, needs, and abilities. As a further aid in this connection, each unit is followed by a list of reading references applying to specific topics discussed in the unit. Also, there are lists of visual aids, including films, lantern slides, and charts.

Not only has care been taken to make the subject matter interesting, unified, and flexible, but special attention has been given to reading difficulty. Both vocabulary and sentence structure have been carefully controlled, and, as already stated, technical terms have been defined or explained and often pronounced at the first point of use. An extensive glossary has been provided to give further help in mastering technical terms. Moreover, the text is liberally supplied with halftones, drawings, charts, and tables to expedite learning and to broaden understanding. All such illustrations should be considered an integral part of the text.

This book represents the first substantial revision of *Dynamic Biology*. The reaction of teachers and students to the original edition has been extremely gratifying. Their suggestions, coming from diversified classroom situations, have been of great value in determining the extent and nature of revisions. The authors and editor are grateful for the favorable reception of the original edition and for the suggestions that have contributed to the present materials.

ARTHUR O. BAKER
LEWIS H. MILLS
Authors

WILLIAM L. CONNOR
Editor

ACKNOWLEDGMENTS

For assistance in the preparation of *Dynamic Biology* the authors are especially indebted to Mr. Lewis J. Rentsch and Mr. Paul Sloan, members of the biology course of study committee of the Cleveland Schools. The authors also wish to acknowledge the assistance of the following:

Dr. William T. Hornaday, authority on wild animal life; Dr. Thurman B. Rice, professor of bacteriology, Indiana University School of Medicine; Dr. Morris Fishbein, editor of the *Journal of the American Medical Association;* Dr. Arthur J. Cramp, director of the Bureau of Investigation, American Medical Association; Russell T. Edwards, director, Educational Section, American Tree Association; Richard W. Westwood, chief of the editorial staff, American Nature Association; Dr. Marion Cleaveland, professor of chemistry, Western Reserve University; Dr. Waldo L. Schmidt, curator of marine invertebrates, Smithsonian Institution, United States National Museum; S. F. Blake, senior botanist, Bureau of Plant Industry, United States Department of Agriculture; Rolla P. Currie, Bureau of Entomology, United States Department of Agriculture; W. B. Bell, Bureau of Biological Survey, United States Department of Agriculture; M. C. Merrill, chief of publications, United States Department of Agriculture; Dr. George H. Sherwood, curator-in-chief, American Museum of Natural History; Dr. Harold L. Madison, curator of education, Cleveland Museum of Natural History; Margaret Cleaveland, librarian, Celia Sprague, instructor, and Mabel Chapman, instructor, all of John Adams High School, Cleveland; Miss A. M. Currin, librarian, Glenville High School, Cleveland; and many other teachers and friends who gave so willingly of time and effort.

Finally, the authors feel greatly indebted to Charles H. Lake, superintendent of Cleveland Schools, whose high standards for the teaching of science and whose sound point of view have served as an inspiration in the building of this book.

DYNAMIC BIOLOGY

UNIT ONE

EXPLORING THE EARTH FOR LIVING THINGS

SUGGESTIONS TO THE TEACHER

The purpose of this introductory unit is to show how life is affected by environment and consequently how life forms are distributed upon the earth. The unit begins with a discussion of life forms that the student already knows. Then it passes to a consideration of forms in other parts of the world. Altogether it gives a picture of the distribution of life in such places as familiar land areas; ponds, lakes, and streams; high mountains; deserts; ocean depths; tropical jungles and seas; regions near the poles; and isolated islands. Along with this picture it establishes an understanding of such necessary terms as flora, fauna, habitat, range, zone, region, and realm. The discussion is general and includes no detailed study of anatomical structure.

In general, the student should read the unit rapidly. The major outcomes are (1) an understanding of the effects of environment, (2) an understanding of the distribution of life forms upon the earth, and (3) a knowledge of certain important definitions. Only the more general principles are presented. Later units will consider life forms in detail and reveal the more subtle adaptations.

OBJECTIVES

I. Facts and principles

A. To learn that life forms are greatly affected by the environment

B. To get a general picture of the distribution of life forms upon the earth

C. To learn important definitions and to understand the relation of biology to other fields of learning

II. Attitudes

A. To get a first glimpse of some of the obvious relations between human life and other living forms

B. To develop an attitude of inquiry and interest in a detailed study of the science of biology

UNIT ONE

EXPLORING THE EARTH FOR LIVING THINGS

JACK MINER AND SOME OF HIS FRIENDS

Courtesy Jack Miner Migratory Bird Foundation

This picture shows Jack Miner and some of the beautiful swans that stop to visit him on their migratory flights. We can readily see from the behavior of these birds that they feel perfectly safe in his presence. The two swans at the right are eating from his hand.

THE STORY OF JACK MINER

PREVIEW

A man stands on the shore of a small lake looking into the distance. Suddenly hundreds of wild geese in graceful formation come into view. They drop swiftly downward and alight upon the water of the lake.

These birds travel southward in the fall and northward in the spring to regions better suited to their needs. They stop along the way to visit Jack Miner, who has demonstrated to

A HAVEN FOR MIGRATORY BIRDS

Courtesy Jack Miner Migratory Bird Foundation

Here we see one of Jack Miner's ponds and a flock of wild geese. Sometimes the birds are so numerous on the ponds that they can scarcely move about.

them that he is a real friend. They come largely because he has provided them with a haven of safety and rest.

Jack Miner lives at Kingsville, Ontario, a small Canadian town near the city of Detroit, Michigan. In 1904 he was a brick manufacturer. Every year he observed migrating birds and thought of their need for food, rest, and protection. Finally he conceived the idea of building a bird sanctuary.

His first step in starting the sanctuary was to transform a clay pit into a lake. He clipped the wings of two wild geese and scattered corn about for food. The two geese and the corn attracted other geese. The first year eleven others came. The second year the number increased to thirty-three, and the third year to three hundred. Today birds come by thousands.

Geese, of course, are not the only birds that come to the sanctuary. Wild ducks, swans, and other interesting birds come by the thousands. Some of these birds like the sanctuary

so well that they deviate from original routes of migration. They fly direct to the sanctuary, knowing that they will find food and protection. As a result thousands of birds have been saved from certain death.

Today Jack Miner is known throughout the world as a friend of birds. His sanctuary includes several lakes and many acres of land. Each year tourists, sometimes ten or fifteen thousand in a day, visit the sanctuary to see what he has done. They go to observe the work of a great man.

PROBLEMS

1. **How do plants and animals adapt themselves to the conditions of their environment?**
2. **What forms of life inhabit fresh-water streams, ponds, and lakes?**
3. **What living things exist on high mountains?**
4. **What forms of life exist on deserts?**
5. **How do organisms differ at various depths in the ocean?**
6. **Why are there so many forms of life in the tropics?**
7. **Why are there so few forms of life near the poles?**
8. **Why do certain islands have peculiar forms of life?**
9. **How may the distribution of living things be summarized?**
10. **What sciences help us in a study of living things?**

Problem 1. How do plants and animals adapt themselves to the conditions of their environment?

THE EFFECTS OF ENVIRONMENT

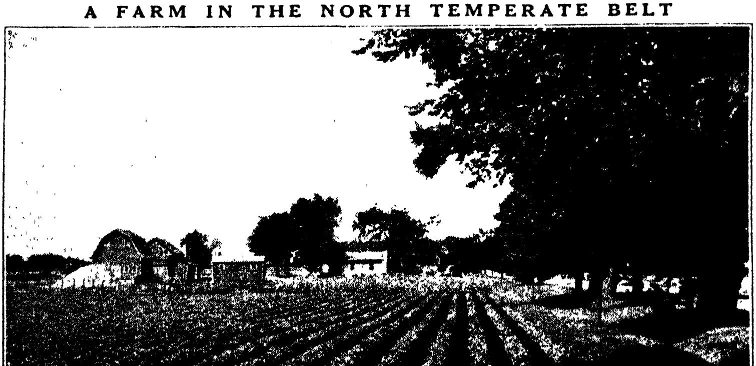
Around us on every hand are interesting forms of life, both plant and animal. Each form has a story all its own. The purpose of *biology* is to help us find out what these stories are. It will help us to know more about living things and consequently to live more in harmony with nature.

The meaning of environment. Every plant and animal is affected by certain conditions of *environment*, such as tempera-

ture, moisture, light, and food. The conditions of environment explain why certain forms of life live in one place and not in another. Large trees, for example, grow near our homes, but they never grow on a desert or near the North Pole. The desert is too dry and the area near the North Pole is too cold. The conditions of environment near our homes are favorable to the growth of trees. The conditions on the desert and near the North Pole are unfavorable. In a similar manner everywhere, conditions are either favorable or unfavorable for the growth of living things.

We live in the North Temperate Belt. This great area extends around the earth midway between the equator and the North Pole and is especially favorable to the growth of living things. It contains the greatest agricultural regions of the world, producing an abundance of farm crops, such as corn, oats, and wheat, and millions of farm animals. Indeed, it is commonly referred to as the bread basket of the world. Moreover, it also provides some of the choicest trees and flowers, as well as numerous wild animals, such as squirrels, rabbits,

A FARM IN THE NORTH TEMPERATE BELT



This farm is merely one of thousands in this country which demonstrate favorable conditions for growth. The crop growing in the field is celery. It will feed many people.

deer, bears, and birds. All in all, then, it is especially favorable to the growth of living things.

The habitat or home. Every organism lives only where conditions are favorable to its growth. The place where an organism ordinarily lives is known as its *habitat.* A habitat is merely a home, such as a pond, a desert, or a high mountain. It is determined by the conditions of environment, such as temperature, moisture, light, and food supply. Thus a frog lives naturally in a pond, but it would soon perish on the desert. A cactus grows naturally on the desert, but it would not survive in a pond.

ADAPTATIONS TO ENVIRONMENT

Why adaptations are found. Most forms of life are adapted to the conditions of their habitat or home. In other words, they have certain characteristics that make them suited to the conditions of their environment. A fish, for example, has gills that enable it to breathe in water. The gills are known as *adaptations.* An adaptation is any modification in the structure or make-up of an organism that makes it suited to the conditions of environment.

A cactus plant has adaptations that make it suited to live on a desert. It possesses few leaves, and even these are of such a nature that little moisture escapes through the process of evaporation. In addition, it has a thick and tough trunk which prevents the escape of moisture. In a similar manner every other living thing is adapted more or less definitely to the conditions of its habitat.

Adaptations to summer and winter. Some of the most interesting adaptations are those which plants and animals make to summer and winter. Many plants grow from seeds. The seeds sprout in the spring and send up plants that grow during the summer. Finally they bear seeds of their own and die down for the winter. Most trees are inactive during the winter. In the spring they manufacture sap, develop leaves, and begin to grow. The dry weather later reduces the production of sap, and by autumn they give up their leaves for winter.

Many animals grow longer hair or fur as a protection in winter. In the spring they shed the protection and consequently keep cool during the summer. Certain animals hibernate or sleep during the winter. The bear eats and grows fat during the summer. Late in the fall he goes into his cave and sleeps until spring. The fat in his body keeps him alive all winter long.

The groundhog and the snake also hibernate. Years ago somebody started the story that on February second each year the groundhog comes out of his hole and looks around. If he sees his shadow, he goes back, for there will be six more weeks of winter. Of course, there is no truth to the story, but it started with the fact that the groundhog hibernates.

Some plants and animals make no noticeable adjustment to winter and summer. Pine trees, for example, retain the same foliage throughout the year. Horses, cattle, hogs, and even man himself, make little, if any, adjustment through their physical structure. Farm animals are kept in barns during the winter and outside during the summer. Man usually wears warmer clothing during the winter than during the summer. The adjustment is outward rather than inward.

The meaning of range. Doubtless we have observed that we often find the same living things where we find the same conditions of environment. For example, we find frogs in nearly every pond, lake, or stream. Each is a separate habitat for the frog. Sometimes the habitats are many miles apart. The area including these habitats is known as a *range*. A range, then, is the general area where a form of life is found. The range for cotton in the United States is from the Atlantic Ocean westward, with interruptions, almost to the Pacific, and northward to Virginia, Tennessee, Arkansas, and Oklahoma.

The life forms in a range, then, are determined by the life forms in the habitats of which it is composed. We should not expect, for instance, to find polar bears near the equator nor tigers near the poles. Ordinarily, fresh-water organisms cannot survive in the salt water of the ocean, nor can salt-water organisms survive in fresh-water ponds, lakes, and

A PLANT WITH A BROKEN RANGE—COTTON

This picture shows cotton in various stages of ripening. As each boll ripens, it bursts open, leaving the white fluffy cotton in the open so that it may be picked.

streams. Many organisms that grow on the slopes and summits of mountains will not survive in lowlands, nor will plants that grow in lowlands survive on mountains.

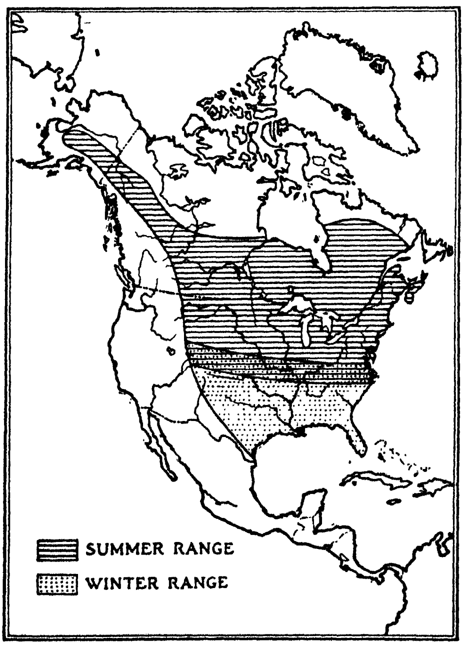
Ranges often broad, broken, or expanded. Certain plants and animals have very broad ranges, being found nearly everywhere, whereas other forms of life have more limited ranges. Some forms have broken ranges; that is, their habitats are separated by expanses of land or water. The cactus plant, for example, is found in the southwestern part of the United States and also along Lake Michigan in the sand dunes of northern Indiana. These two areas are hundreds of miles apart. Cotton, as already stated, grows over a large area, but there are many places within the area where no cotton may be found. Its range, therefore, is broken.

Sometimes the range of plant or animal is expanded. A notable example is the so-called Irish potato. This plant is a native of the Peruvian and Chilean Andes in South America. Early explorers carried it to Ireland, where it became so popular

that it was named the Irish potato. Today it is grown successfully and is one of the chief articles of diet in many parts of the world. Another example of a life form that has expanded its range is the rabbit. This animal is a native of southern Europe and northern Africa. An Englishman carried a few of these animals to Australia. Today their numbers have multiplied so rapidly that rabbits are a menace.

The range of birds. The term range is also applied to the area over which certain birds migrate. For example, the range of wild geese and wild ducks extends from the southern part of the United States to the region around Hudson Bay in Canada. The range of the robin extends from Mexico on the south to Alaska on the north. For migratory birds there are really two ranges, one for the summer and another for the winter. The summer range is the area where the bird may be found during the summer. The winter range is the area where it may be found during the winter. The illustration on this page shows the summer and winter ranges of the robin.

THE RANGES OF THE ROBIN



Courtesy Spencer Lens Company

The map shows the winter and summer ranges of the robin. If we could follow one of the robins that visit us during the warmer months, we should be surprised at how far it travels in its migratory flights.

Life zone—a common range of plants and animals. Some plants and animals have the same range; that is, they grow in the same general area. Near where we live, for example, there may be

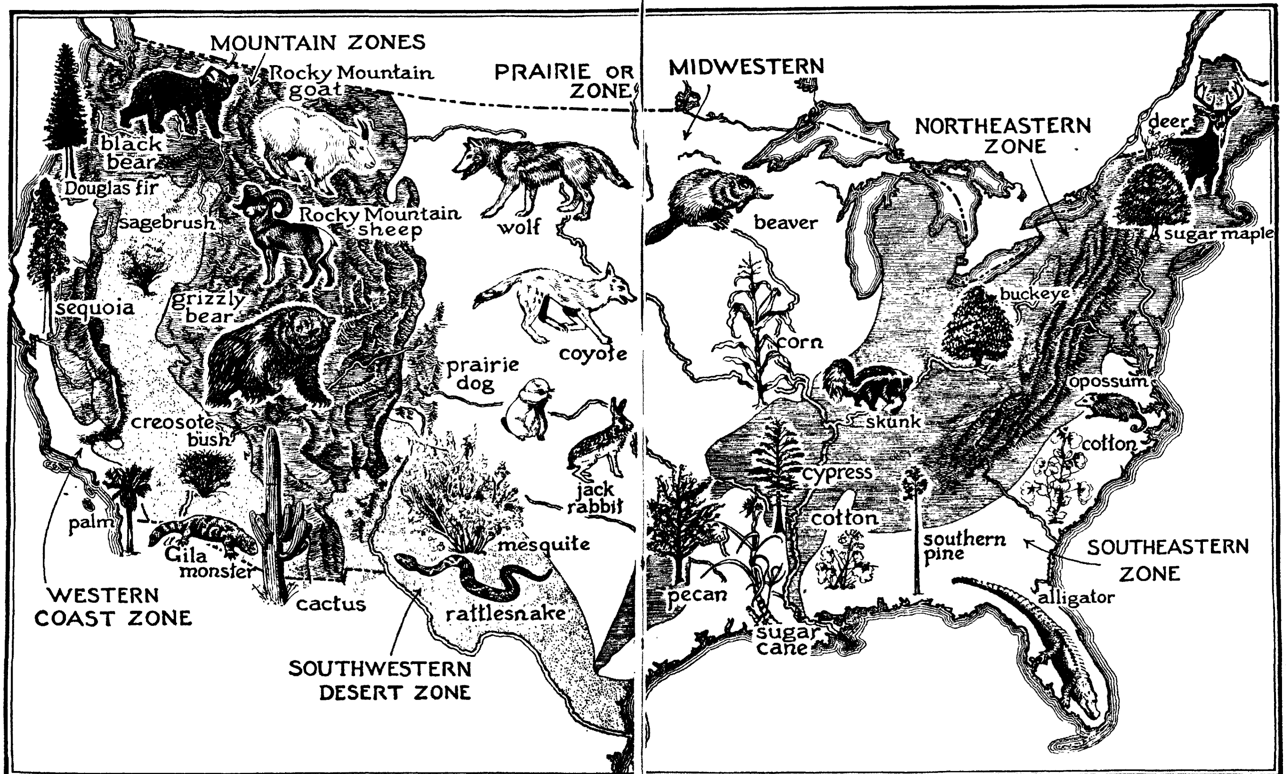
such animals as robins, crows, horses, cattle, hogs, and sheep. There may be such plants as dandelions, grapevines, maple trees, potatoes, corn, wheat, and oats. All these forms of life may be said to have a common range. They are suited to the same general conditions of environment.

An area which serves as a common range for certain plants and animals is called a *life zone*. It is determined largely by such geographical factors as climate, elevation, and character of the soil. Some of the more important zones in the United States are as follows: (1) the northeastern zone, extending from Lake Michigan eastward to the Atlantic Ocean; (2) the southeastern zone, extending from Virginia to Louisiana; (3) the prairie or midwestern zone, extending eastward from the dry grasslands just east of the Rocky Mountains and including the great central part of the country; (4) the mountain zone, including the higher mountain tops of the Rocky Mountains and the mountains farther west; (5) the southwestern desert zone, including the dry plateaus to the north of Mexico; and (6) the western coast zone, including productive lands along the Pacific Coast. The extent of each zone is shown on the map on the two following pages.

The plants of a certain zone are known as *flora* and the animals are known as *fauna*. Therefore we may speak of all the plants of a certain zone as belonging to the same flora and all the animals as belonging to the same fauna. The flora and fauna of certain zones are especially interesting. The plants and animals of the southwestern desert zone, for example, are interesting because of their adaptations to a very dry climate. They differ greatly from the plants and animals in the other zones of the United States where there is considerably more rain.

Usually the boundary lines between zones are not sharply defined. In going from the southwestern zone to the prairie or midwestern zone, we should find it hard to tell where the one ends and the other begins. Such an area is often called a *transition zone* because it really contains the flora and fauna of two adjoining zones rather than of one.

SOME LIFE ZONES OF THE UNITED STATES



This illustration shows a few of the more familiar life zones of the United States. Altogether there are probably as many as fifty distinct zones within the country.

Region—an area made up of life zones having similar flora and fauna. The plants and animals in certain life zones are often similar to those in other life zones. They are similar because the climate, the altitude, and the character of the soil are somewhat similar. In other words, the forms of life in the zones make similar adaptations to the environment. An area made up of neighboring life zones that possess similar flora and fauna is known as a *region*. A region, then, is much larger than a zone.

The main regions of the United States are as follows: (1) the area extending from the lands just east of the Rocky Mountains eastward to the Atlantic Ocean and southward nearly to the Gulf of Mexico; (2) most of the state of Florida and other lands bordering the Gulf of Mexico; (3) the area extending from the Rocky Mountains westward except for certain lands in the southern part where the flora and fauna resemble those of Florida and other lands along the Gulf of Mexico. In general, life forms west of the Rockies show greater diversity than those east of the Rockies. This happens because the country has a more irregular surface and greater variations in rainfall.

Realm—an area made up of regions. Certain groups of regions, such as those in North America, are cut off from others, as those in South America, by impassable, or nearly impassable, barriers. These barriers prevent life forms from moving from one area to another. As a result, life forms differ more than they would if mingling could take place. A group of neighboring regions cut off from other regions in the world is called a *realm*.

The major realms in the world are as follows: the North American, South American, Eurasian, African, Oriental, Australian, Antarctic, and the ocean depths. These realms make up the broadest canvas upon which the interesting picture of adaptation may be painted. If we apply our knowledge of geography, we can readily understand why the various realms exist. We can also get a better understanding by looking at the maps on the following pages.

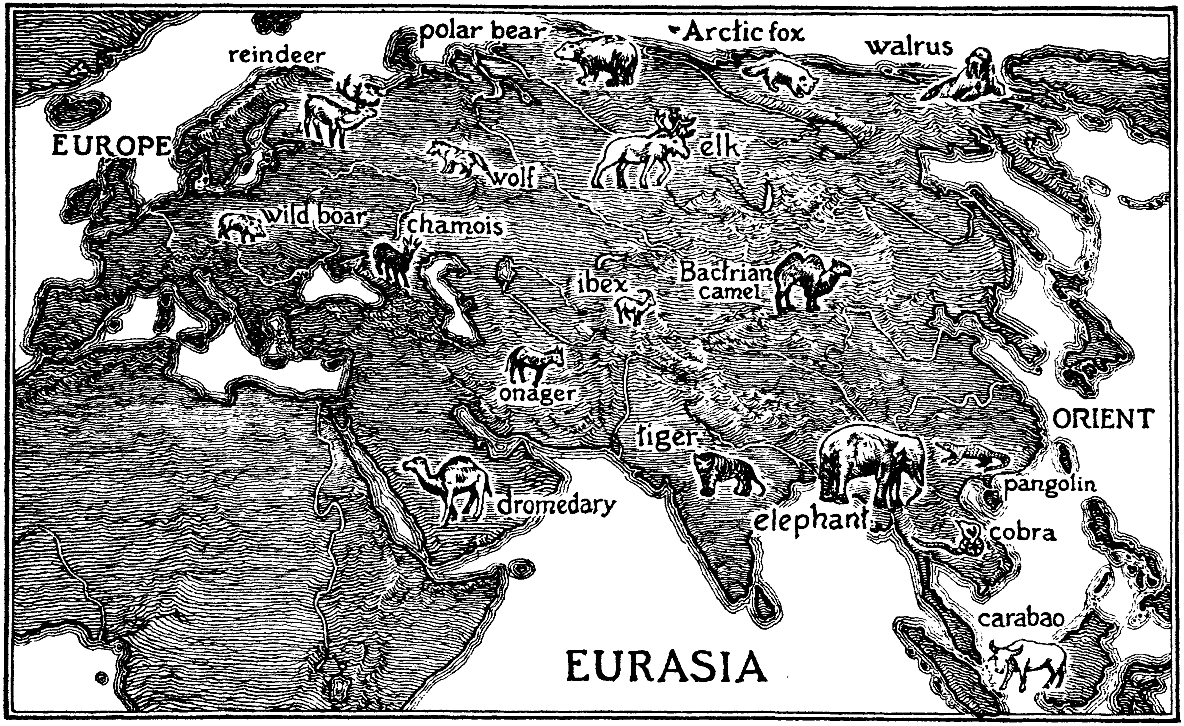
ONE LIFE REALM OF THE WESTERN HEMISPHERE

Which of the animals shown on this map have you seen?

THE OTHER LIFE REALM OF THE WESTERN HEMISPHERE

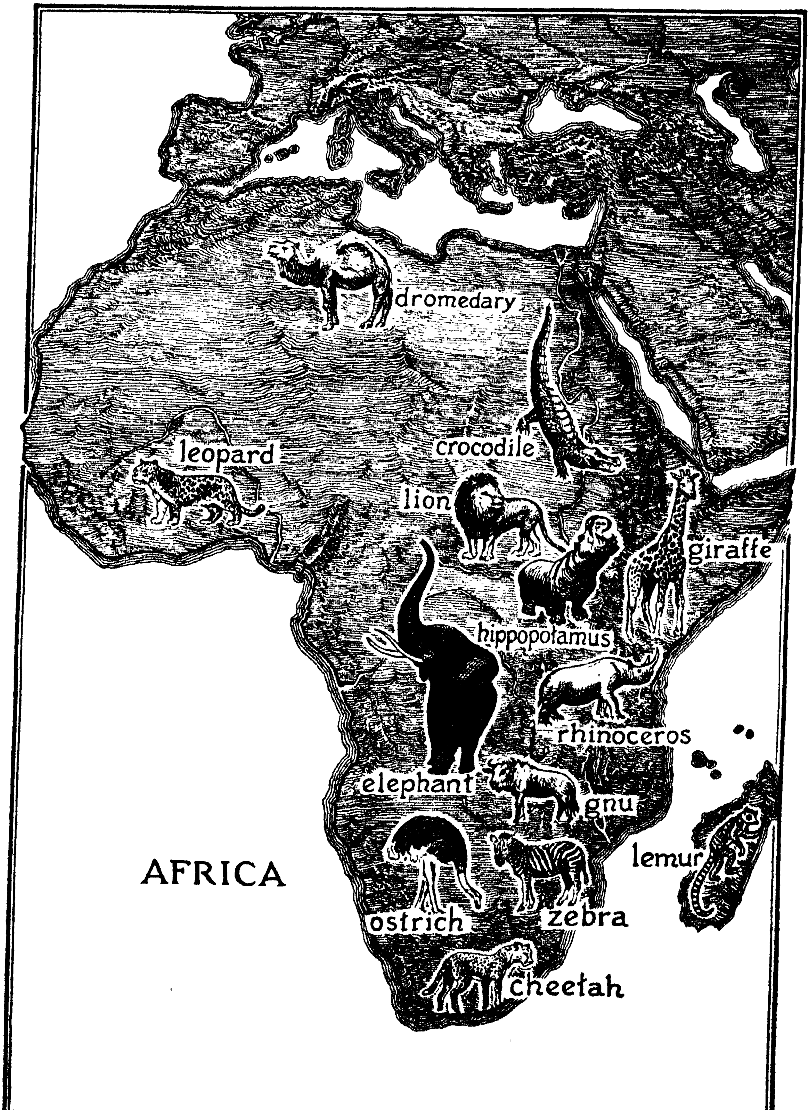
How do these animals compare with those of North America?

TWO LIFE REALMS OF THE EASTERN HEMISPHERE



All of Europe and Asia belong to the Eurasian realm with the exception of southeastern Asia, which belongs to the Oriental realm.

ANOTHER LIFE REALM OF THE EASTERN HEMISPHERE



This realm contains some of the most interesting animals in the world.

THE ISLAND CONTINENT—AN ISOLATED REALM

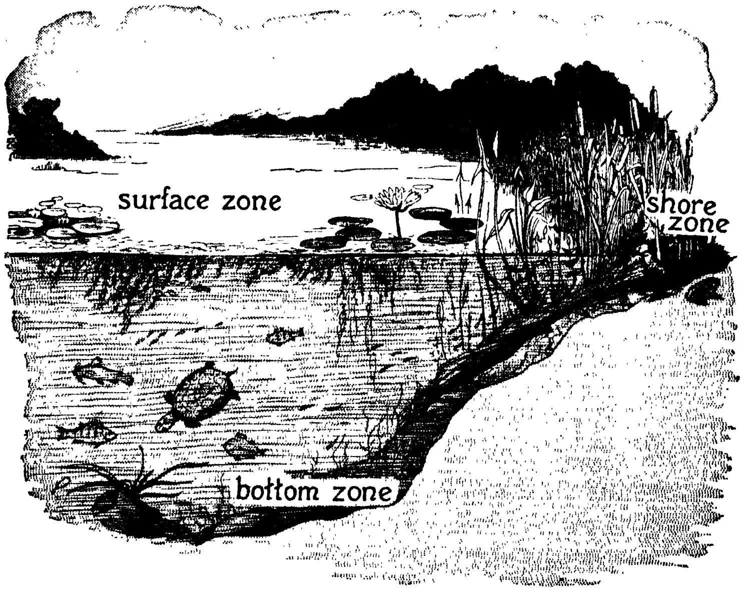
The island continent of Australia is far away from most of the other continents and contains some very strange forms of life.

Problem 2. What forms of life inhabit fresh-water streams, ponds, and lakes?

ABUNDANT LIFE IN FRESH WATER

Perhaps we live in the vicinity of a fresh-water lake, pond, or stream. Even so, we may fail to realize that fresh water usually contains many forms of life. Certain forms, such as lilies, swamp grasses, fish, and frogs, are readily apparent because of their size. Others are not in evidence because they are exceedingly small, some being microscopic in size. Altogether a single stream or body of water may contain a thousand or more different forms of life. Therefore within a short distance from home we doubtless have an excellent opportunity to conduct many interesting investigations, especially if we are fortunate enough to possess a microscope.

DISTRIBUTION OF LIFE IN PONDS AND LAKES



This drawing shows how certain plants and animals distribute themselves in a body of fresh water. Which zone is the most favorable to growth? the least favorable?

Living Conditions in Fresh Water

Plants and animals usually distribute themselves in a pond or lake according to a pattern. Some live near the shore and others away from the shore. Some live near the surface and some near the bottom. All these different places in the water are commonly known as *zones*. The term zone used in this connection, however, should not be confused with the term *life zone* meaning a common range.

The forms of life distribute themselves because of differences in conditions in different parts of the water. The conditions near the shore are different from those away from the shore. Those at the surface are different from those at the bottom. The factors which affect living things most in fresh-water lakes and ponds are temperature, oxygen, sunlight, movement, and impurities.

The temperature factor. In general, a water habitat is favorable to the growth of organisms because the temperature of the water changes more slowly than that of land or air. The larger a body of water, the more constant is the temperature. Deep water is colder and more uniform in temperature than that near the surface. Water organisms, therefore, suffer less from changes of temperature than do those on land. Sudden changes on land often result in the death of a great many forms, especially plants.

The oxygen factor. This factor is one of the most important because some organisms can secure oxygen readily in water whereas others cannot. Fish, for example, secure oxygen in water because of breathing organs called gills. These organs consist of very thin membranes that allow the oxygen to pass directly into the blood. Thus the gills serve fish much as lungs serve animals that live on the land.

Certain organisms that have no means of taking oxygen from water live on the surface. The water lily, for example, spreads its leaves on the surface so that it may take oxygen from the air. Many aquatic insects swim or float about on the surface because they must take in oxygen directly from the air. A few beetles and bugs carry, under their front wings,

air bubbles that enable them to go beneath the surface and stay for variable periods of time.

The water along the shore usually contains much more oxygen than that farther away. This is because it is much closer to the air than is the deeper water near the center. Also, the shallow water near the shore contains smaller quantities of poisonous gases, such as carbon dioxide, than does the deeper water near the center. Sluggish streams contain greater quantities of carbon dioxide than rapidly moving ones. Rapidly moving streams, on the other hand, are much better aërated, that is, better supplied with air than sluggish ones. Active forms of animals that require much oxygen usually live and thrive in moving water much better than they do in sluggish water.

The sunlight factor. Light rays ordinarily have a great effect upon the distribution of aquatic plants and animals. If the water is clear, the rays penetrate deeply, but if it is muddy, they penetrate only a few feet. Therefore plant life is limited largely to the surface or to shallow water along the shore. Some animals stay near the surface at night and at lower depths during the day.

The movement factor. The circulation or movement of water affects life in a variety of ways. As already indicated, moving water provides much more oxygen than quiet water does. On the other hand, it has certain drawbacks. The current of swift-moving streams, for example, may erode or wear away so much soil on the bottom that plants cannot take root. As a result, the bed of a sluggish stream is much more favorable to growth.

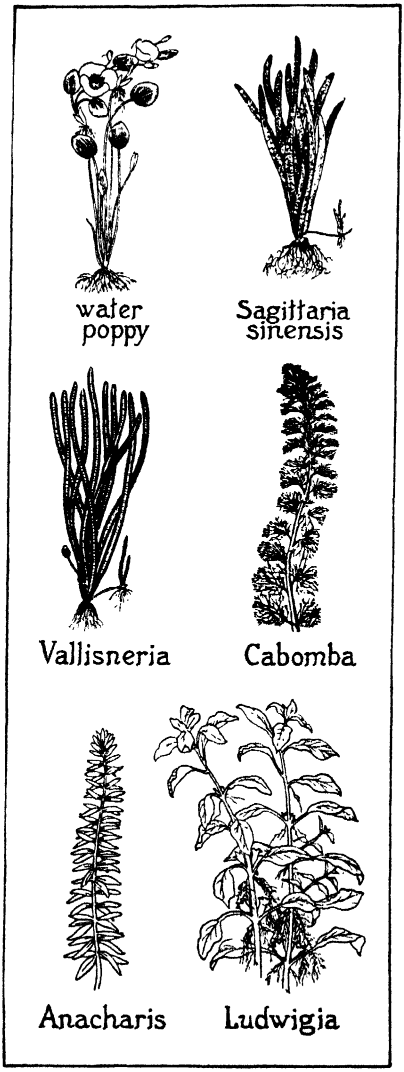
The impurities factor. Many forms of life cannot grow in water that is impure. In certain localities factories and mills empty their wastes into near-by streams or lakes. These wastes tend to destroy all forms of life. If we were to examine under the microscope a few drops of water from such streams or lakes, we should find that they contain no forms of life. The wastes either make the water poisonous to plants and animals or too thick for them to use as a habitat.

PLANT LIFE OF THE PONDS

Courtesy William Tricker, Inc.

Water lilies, cat-tails, arrowheads, and rushes add to the beauty and variety of fresh-water ponds.

PLANTS THAT SUPPLY OXYGEN TO PONDS



Courtesy William Tricker, Inc.

The plants shown above help to keep the water in ponds, lakes, and streams fresh by supplying oxygen.

In order for plants and animals to thrive in water, it must contain a certain balance of the gases oxygen and carbon dioxide, as well as a certain quantity of minerals. The water from factories and mills often disturbs the balance of oxygen and carbon dioxide and adds to the mineral salts. As a result the *protoplasm* (prō′tō-plăz'm), or living matter in the cells, fails to receive proper nourishment and consequently dies.

Just as plants and animals cannot live in water that contains wastes, neither can they live in water that has been distilled. When there are no minerals, or a very low percentage, the effect is about the same as when the percentage is high.

INTERESTING LIFE FORMS IN FRESH WATER

Fresh-water plants. Aquatic forms of life are usually very interesting. They are interesting because of their peculiar adaptations to environment. The variety of forms is exceedingly great. Only a few of them, however, may be mentioned here.

Most plants that grow in water extend their leaves above the surface of the water. The water lily has a long flexible stem that enables its leaves to rise and fall with the surface of the water. Other interesting plants that extend their leaves are the pickerel weed, rush, arrowhead, and sedge. A few plants, such as the *Vallisneria* (văl′ĭs-nē′rĭ-ȧ), commonly called eelgrass, have long ribbon-like leaves that continue to live even when submerged. Still other plants have no roots anchored in the soil and merely float about. An example is the water hyacinth, which floats because its leaves contain a spongy substance that holds air.

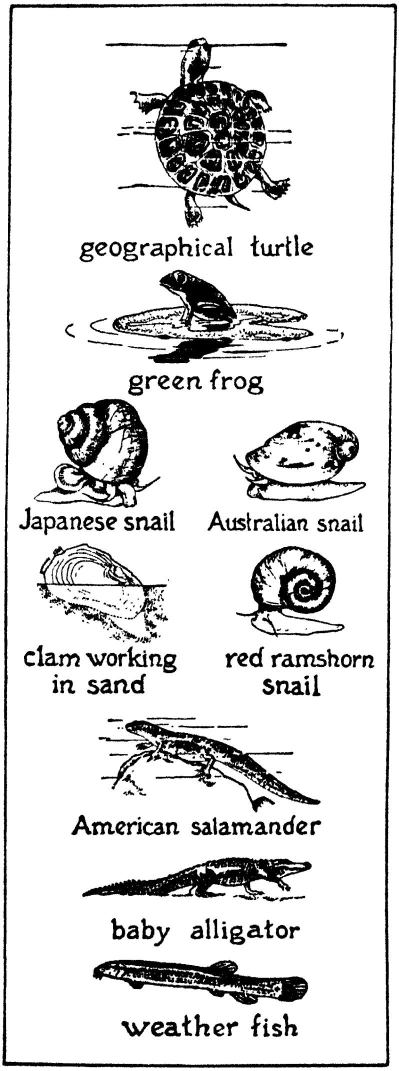
Among the most interesting of the fresh-water plants are the *algae* (ăl′jē), which are found both in rapidly running streams and in very quiet ponds. Most of them are microscopic in size. They often congregate, however, and form a conspicuous mass, which we see as a green scum on the surface of stagnant pools.

All fresh water contains bacteria, important forms of microscopic plants. A cubic centimeter of ordinary lake water contains several hundred bacteria. A cubic centimeter of river water contains many more, often several thousand. Bacteria are usually much more numerous in surface water than they are in deep water.

Fresh-water animals. Minute aquatic forms of plant and animal life together are often designated as *plankton*. Such forms serve as a main article of diet for larger aquatic animals. Most fresh-water animals are very small. The most abundant forms are the *Protozoa* (prō′tȯ-zō′ȧ), or one-celled types, which, of course, must be examined with a microscope. Other forms are insects and their larvae, flatworms, roundworms, crayfish, mussels or clams, and snails.

As already stated, most aquatic forms of life have made interesting adaptations to their environment. These adaptations may be studied best by the use of an aquarium. Anybody who is skillful with tools may readily make an aquarium, or he may purchase one at very low cost. The aquarium will be most interesting when stocked with a variety of tenants.

ANIMALS THAT INHABIT FRESH WATER



Courtesy William Tricker, Inc.

These animals, of course, are only a few of the interesting forms to be found in fresh-water ponds, lakes, and streams.

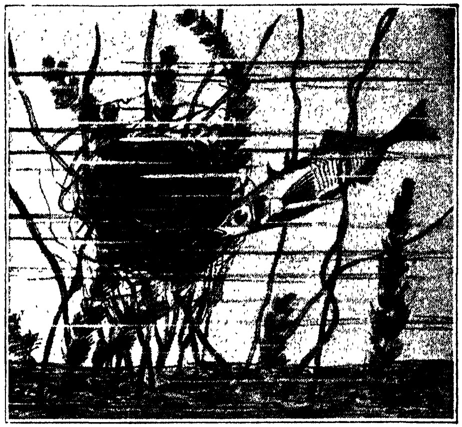
Besides fish, it may contain numerous other animals, such as newts, small crayfish, mussels, and snails; and various plants, such as eelgrass, the smaller arrowheads, and water weed. An aquarium of this type is much more interesting than one of the usual type which is stocked only with goldfish.

Insects are primarily land animals, but, as has already been indicated, bugs and beetles often float about on the surface of water. Certain insects can breathe under water during immature stages but later must take oxygen from the air. An example of such insects is the dragon fly, which lives in the water for a period varying from a few months to two years before reaching the adult stage.

Of course, the most widely known fresh-water animals are fish. In most areas, therefore, it is easy to secure specimens of fish for a study of adaptations to a water habitat. Among the many fresh-water fish in North America are the trout, bass, catfish, pike, pickerel, sunfish, and stickleback.

Some of these species of fish have extremely interesting habits. Let us consider, for example, the activities of the small-mouthed bass. The male hollows out a nest with his fins on the gravel bottom of a shallow stream. Then after the spawning process he drives the female away, protects the eggs, and later attends the little ones until they can take care of themselves.

A FRESH-WATER NEST BUILDER



Courtesy *World Book Encyclopedia*

While most fish deposit their eggs in hollows which they scoop out in the bottom of streams, the stickleback is the only fish that really builds a nest. It builds its nest largely of sticks and roots as shown above.

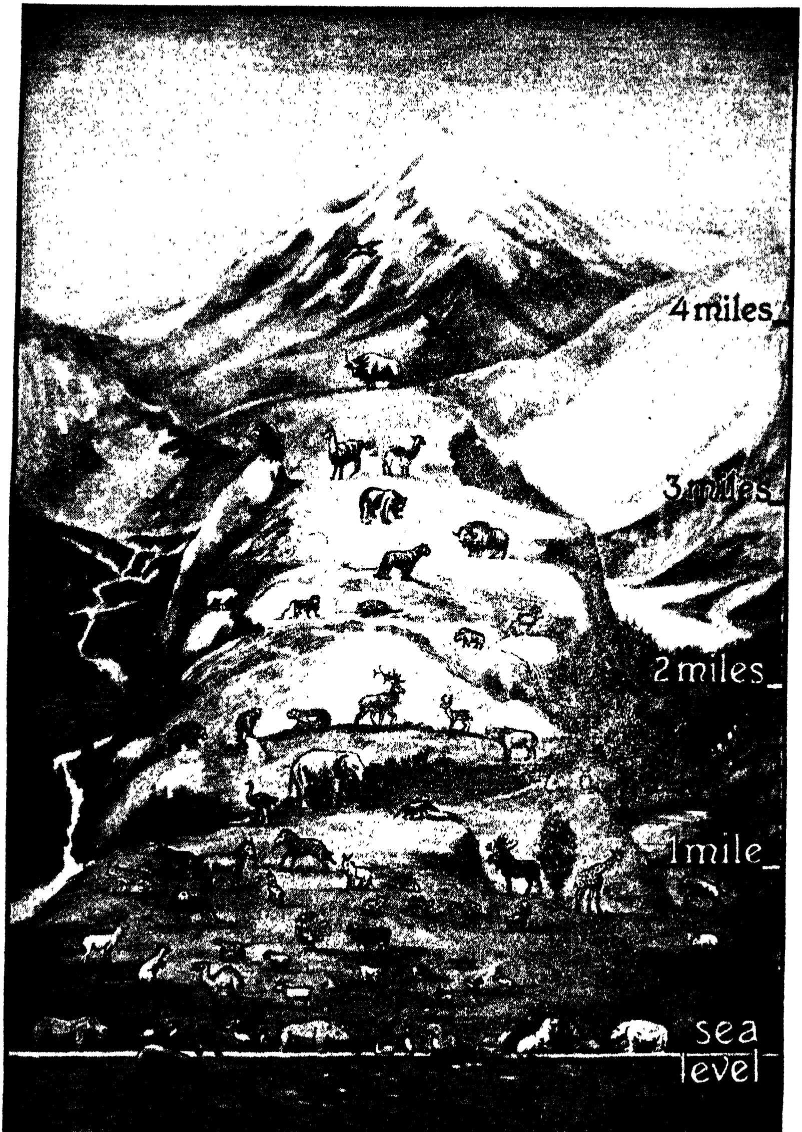
Many forms of animals, such as minks, muskrats, moles, beavers, otters, frogs, toads, water snakes, kingfishers, and ducks, make their homes in or near the water. Such a habitat affords plenty of food and serves as a refuge from enemies. When we compare animals that live in or near the water with those that live entirely on land, we can readily see many evidences of adaptation. The gills, fins, and "streamlined" shape of a fish, for example, make it well suited to life in the water. The same adaptations make it poorly suited to life on land. In fact, when a fish is taken from the water it can survive only a very short time, usually less than an hour.

Problem 3. What living things exist on high mountains?

LIFE ON THE MOUNTAINS

In the western part of the United States, as we know, is a very large area which we have come to know as the Rocky Mountains. Whenever a person ascends the sides of these

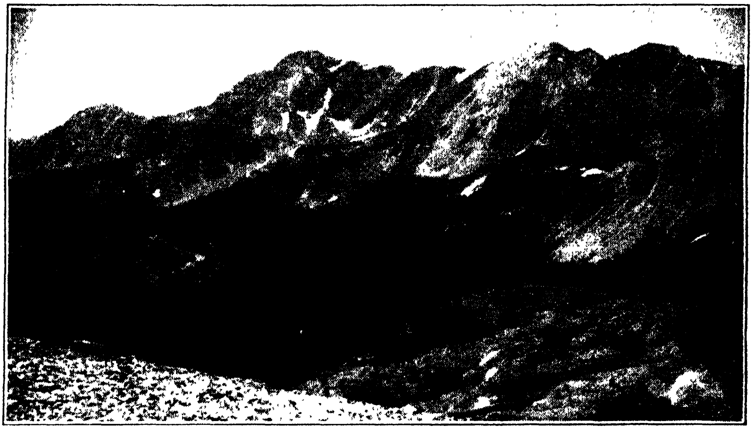
LIFE ZONES ON THE MOUNTAINS



Courtesy *New Wonder World*

This picture shows the larger forms of life to be found at various heights above the sea. Notice that the forms are more numerous on the lower slopes than on the higher ones.

THE TREE LINE ON A MOUNTAIN



Courtesy U. S. Forest Service

The lower slopes of this mountain are covered with trees. They grow only to a certain elevation known as the tree line. Above this line the slopes are almost bare.

mountains, he notices many changing conditions. For one thing, he finds a decrease in temperature all the way to the summits. An ascent of 1,000 feet is approximately equivalent to an advance northward of three degrees in latitude. The traveler also notes a great increase in the velocity of the wind as he ascends a mountain. At an altitude of about 11,000 feet he may find the wind so strong that trees are greatly bent and stunted in their growth.

The temperature on high mountains is very changeable. During the night it is usually very cold, often far below freezing. During the day, however, if the weather is clear, it may become rather warm. Thus plants and animals found on the higher mountain zones must be able to withstand great changes of temperature.

Plants on the mountains. Often at the base of a mountain there are very few plants because of a barren expanse of rocks and the absence of moisture. On the windward side, however, there may be considerable rainfall and hence luxuriant vegetation. The lower slopes may be covered with forests, principally of pine, fir, and spruce. The trees grow only to a certain

AN INHABITANT OF THE SUMMITS

Hileman

This picture shows a Rocky Mountain goat, an animal well adapted to climbing and jumping.

elevation known as the tree line. Above the tree line the temperature is low and the vegetation is small and scattered. It consists largely of such plants as dwarf birches and willows and plants bearing brilliantly colored flowers. The willows, which sometimes attain a height of thirty or forty feet on lower lands, are generally only about an inch tall on high mountains. The tops of the highest mountains, of course, are covered with snow the year round.

One of the most interesting forms of life on the highest mountains is a species of red algae. These algae live on snow and give it a red color. Therefore, if we were to climb certain high mountains in Colorado, we should find patches of red snow! The red color of the algae enables them to absorb heat very readily. This explains why they can live in such a very cold habitat.

Animals on the mountains. Many animals find the mountains a desirable habitat because they provide good hiding places. On the wooded slopes we often find such interesting animals as the deer, bear, fox, wolf, raccoon, otter, and various kinds of squirrels. Such mountains have many snakes, sometimes rattlesnakes.

Certain animals in the mountains are very good climbers. One of the best is the Rocky Mountain goat. This agile animal climbs ledges and crests with amazing fleetness and accuracy. Because of its expertness it is able to escape a great many enemies. Then, too, during the summer and fall it is

able to reach high mountain pastures. When the snow comes in winter, the goat descends to lower elevations, where it feeds upon the dried vegetation of the slopes.

Animals that often find the mountains a desirable habitat are little mountain beavers. These interesting creatures, despite their clumsiness, sometimes live as high as 10,000 feet or more, and build their dams in mountain streams. A few birds and numerous insects, such as crickets, butterflies, and beetles, also live high in the mountains.

Problem 4. What forms of life exist on deserts?

DESERT FLORA AND FAUNA

Conditions on deserts, like those on mountain tops, are unfavorable to the growth of most living things. In order to survive, they must withstand great lack of moisture and

PLANTS THAT THRIVE IN DESERT SANDS

Desert plants often have large, expansive stems, which enable them to store large quantities of water. What adaptations do they sometimes make in their roots and leaves?

in some places exceedingly high temperatures. Often the soil would support abundant plant life if there were sufficient moisture. This fact is proved by the many forms of life that are found on irrigated lands and oases.

Sagebrush and other plants of the desert. Desert plants have made a number of interesting adaptations. Some of them have much longer roots than ordinary plants, enabling them to absorb moisture at far greater depths. Among the plants with long roots are sagebrush and mesquite, which

"SHIPS OF THE DESERT"—CAMELS

William Thompson

How is the camel adapted to the conditions on the desert? Some camels have one hump on the back and others have two. Those in the picture, known as Bactrian camels, have two. Both types are especially well suited to carrying goods.

have more wood in the ground than above it. Other desert plants have almost no roots at all, requiring little moisture in order to keep alive. Most desert plants have small leaves that enable them to hold down the process of evaporation and hence to conserve their moisture. The leaves of the cactus, for example, have the shape of spines.

Animals of the desert. Like plants, desert animals have made many interesting adaptations. One of the best-known desert animals is the camel. This creature stores water in a water pouch and fat in a hump, thereby enabling itself to go for days without food or drink. It has flat, cushioned feet that enable it to walk on top of the sand.

Another unusual characteristic of the camel is its double eyelids. The outer lids are the same as those of other animals, but the inner eyelids are transparent. Therefore the inner lids may be closed without obscuring the vision. The camel can also close its nostrils as a protection against drifting sand. All in all, then, we find the camel suprisingly well adapted to life on the desert.

Other animals adapted to life on the desert are the wild antelope, gazelle, goat, donkey, coyote, puma, and jack rabbit. In addition there are many reptiles, such as rattlesnakes and horned toads. All these animals require little water and thrive in a warm climate.

Problem 5. How do organisms differ at various depths in the ocean?

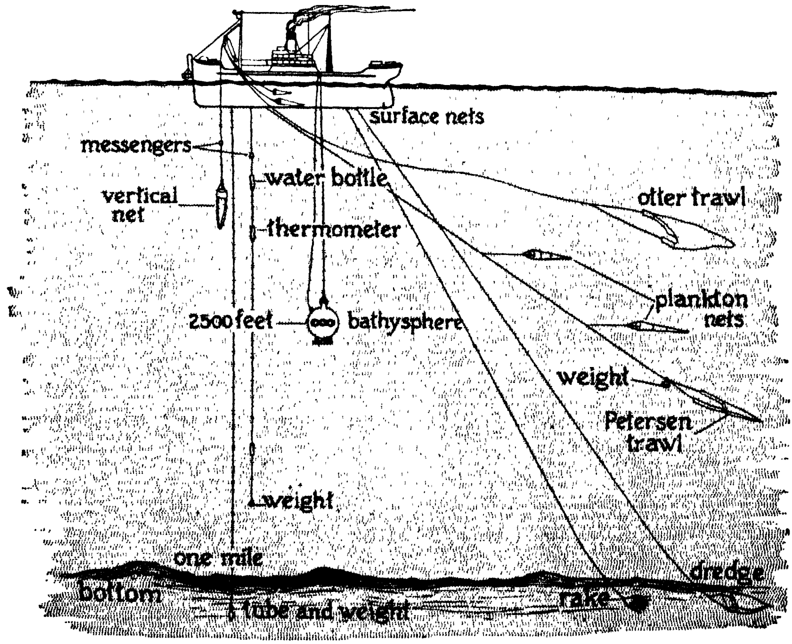
LIFE IN THE DEEP SEA

Like fresh bodies of water, the sea is divided into zones. The forms of life differ at different depths in the sea. The forms found near the surface are never found at very great depths. If we were to explore ocean depths, we should find that light fades as we go deeper, until at 650 feet below the surface there is only twilight. Farther down we should soon come to a region of total darkness, where no plants can live, with the exception perhaps of bacteria. At this depth and below, then, we should expect to find only animals.

The temperature, we should find, also becomes lower and lower away from the surface. If we were to descend far enough, we should come to a place where the water is nearly freezing regardless of how warm it is at the surface. Below this point, even to the bottom, the temperature remains fairly constant. This is partly because the water is quiet, there being practically no disturbances from the surface.

If we were to continue our explorations, we should find that the pressure or weight of the water constantly increases as we descend. At a depth of 15,000 feet it becomes two and one-half tons or more to the square inch. Some animals can withstand such a great pressure and some cannot. Consequently, pressure is an important factor in determining zones.

EQUIPMENT USED IN EXPLORING THE DEEP SEA

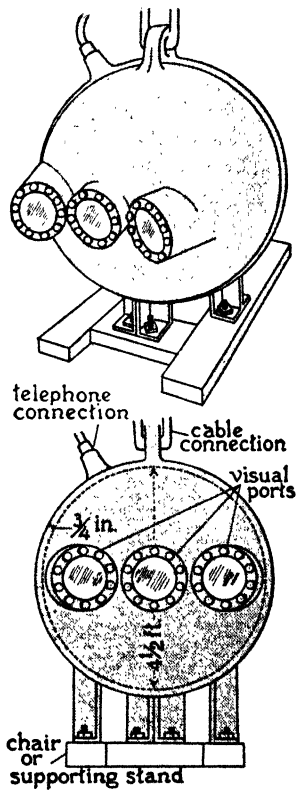


This drawing shows equipment used in exploring the deep sea. Notice the nets, trawls, rake, bathysphere, thermometer, and various other devices. How does each help in exploration?

These factors explain why there are different zones and why the forms of life differ at different depths. In general, the larger forms live near the surface. The forms in deep water probably owe their origin to those at or near the surface, but they have made many interesting adaptations.

How ocean depths are explored. Scientists have studied the water of the sea to a depth of six miles or more. Often they collect specimens of living organisms by the use of dredgers. In such a case they scoop up the forms of life along with sand and mud from the bottom. At other times they lower trawl-nets, which they drag along the bottom. They also use nets for catching animals in the intermediate depths. In addition to the specimens themselves, scientists study the depth, pressure, and temperature of the water. Many instruments have been devised for these purposes. Ships used in such investigations have so much special equipment that they seem like floating laboratories.

THE BATHYSPHERE



This drawing shows a bathysphere such as Charles William Beebe used for exploring the deep sea. Notice the visual ports and the connections with the surface.

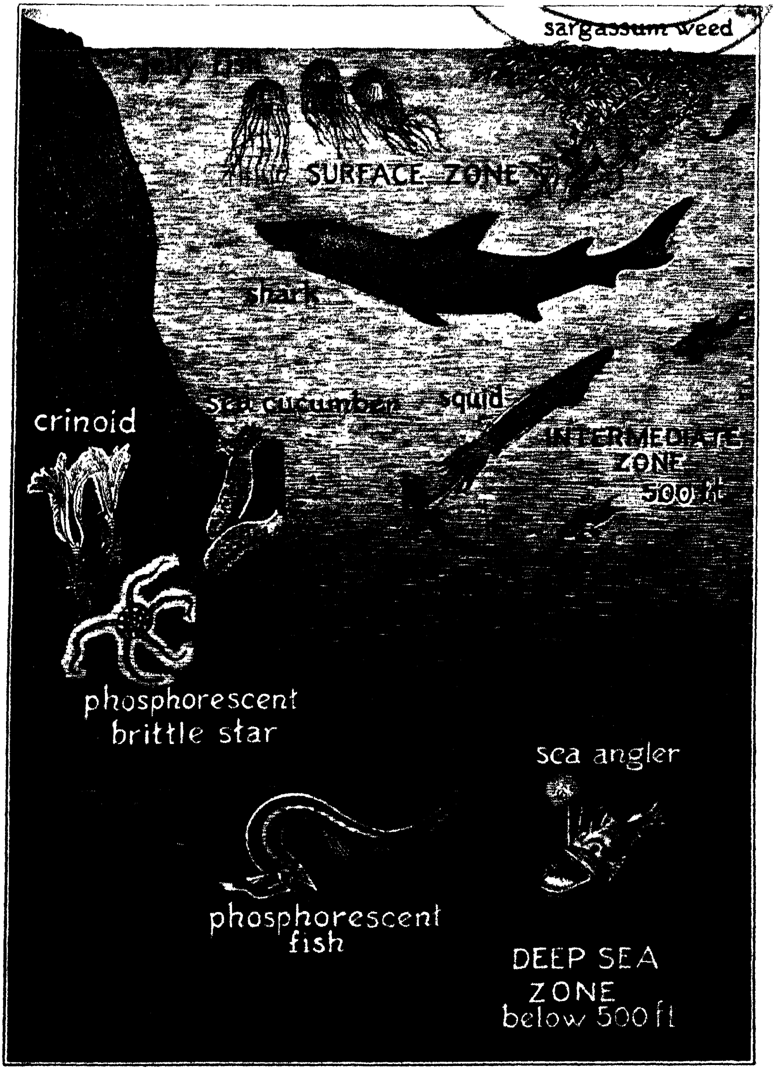
A few years ago a noted scientist, Charles William Beebe, set a new pace in exploring deep waters. He actually descended a half-mile below the surface in a large steel ball called a bathysphere (băth'ĭ-sfēr'). This ball was four and one-half feet in diameter, with walls one and one-quarter inches thick. The entrance door of the sphere weighed five hundred pounds. The sphere was equipped with telephone wires for maintaining contact with the helpers at the surface. It also contained

oxygen tanks to supply pure air for breathing. The sphere was lowered by means of a heavy steel cable. As Beebe descended, he stopped every five hundred feet to photograph fish and other deep-sea life outside the portholes. Thus he secured many interesting facts about life in the ocean depths. Even so, of course, he could see only a small part of what the cold, dark water contains. Further study will doubtless uncover much additional information about the life of the deep.

Plants of the sea. Practically all the plants of the sea are found at or near the surface. This is because they must have sunlight to enable them to manufacture food. Plants may grow fairly well to a depth of about two hundred feet. Below six hundred feet only bacteria are to be found. Most plants of the sea belong to a group known as *marine algae.* These plants have no real roots and very few branches. Some are provided with floats and others with mechanisms for attaching themselves to rocks or whatever happens to be near. They range all the way from very delicate forms to the hardy sargassum weed. Most of them serve as food for animals. One of the greatest masses of floating seaweed is commonly known as the Sargasso Sea. It was discovered by Columbus on the famous trip on which he also found the New World.

Animals of the sea. Many estimates have been made of the number of animals that may be found in the sea. Nobody, of course, can be certain, but it is known that there are thousands and thousands of forms. Most of these forms live near the surface or in shallow water. This is because most of the green plants are found near the surface. These plants not only provide food but also liberate oxygen, which the animals need for breathing. Hence the surface zone of the sea provides a balanced relationship between plant and animal life. Among the animals that exist in this zone are the well-known forms of whales, seals, sea turtles, sharks, and numerous forms of fish. There are also countless forms that are less well known, especially smaller forms, many of them microscopic. Naturally, all the forms of life in the highest zone resemble land forms much more closely than do those at greater depths.

LIFE ZONES OF THE SEA



This drawing helps to explain the different life zones of the sea. Which zone has the greatest abundance of life? How do the forms of life differ from zone to zone? Which zone has no plant life except bacteria? Which zone has total darkness?

The forms of life in the dimly lighted zones below the highest zone are very interesting. Here we find starfish, ugly sea urchins, squids, and many strange-looking crabs. Deeper, we find a zone where all the animals are silver in color and, at a still lower depth, a zone where they are red and black. Often, as these forms of life die and sink to the bottom, they give the bottom a reddish color. Below the red and black forms of life are such forms as corals, sponges, mollusks (mŏl′ŭsks), sea anemones (ȧ-nĕm′ō-nēz), sea pens, and various bony fish. Sometimes the corals and sea anemones look so much like trees and flowers that the bottom of the sea has the appearance of a submerged forest.

Among the wonders of the deep sea are luminous or phosphorescent fish. These fish have many fantastic shapes and colors and give the zones of the deep sea a touch of wonder and mystery. Most of them have illuminating organs on their heads somewhat like the headlights of an automobile. Many of these headlights take the place of eyes. Some of the fish have illuminating organs on the sides and look like far-away lighted ocean liners in the darkness of the night. It is noteworthy that many of the fish are blind.

Problem 6. Why are there so many forms of life in the tropics?

THE FLORA AND FAUNA ALONG THE EQUATOR

Along the equator in Africa and South America is an area known as the equatorial rain belt because of its excessive rainfall. Here life exists in great abundance and variety. The heavy rainfall and an almost constant high temperature are extremely favorable to the growth of many plants. These conditions, either directly or indirectly, are likewise favorable to the growth of many animals. Let us now consider some of the forms of life to see what they are like.

Land plants along the equator. In the Amazon Valley of South America and in the Congo Basin of Africa there are two types of vegetation: (1) the rain forests, in which it rains

almost daily all the year round; and (2) the savannas, which border the rain forests on the north and the south, but which in themselves have periods of rain interrupted by periods of drought. The vegetation in the rain forests is extremely luxuriant. Many kinds of trees spread their tops in dense layers above the ground. The tops of the taller trees form a canopy over the lower ones and get most of the light. In addition to the many trees, there is an interesting interlacing of vines. All this dense vegetation forms a hot, dark, impenetrable area known as the jungle. Typical trees of the jungle are rosewood, mahogany, and rubber.

A MIGHTY BOA CONSTRICTOR AT REST

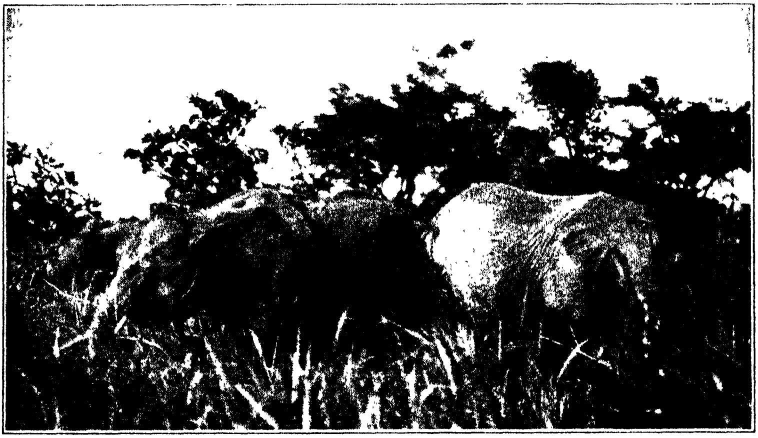
Century Photos

The boa constrictor spends much of its time resting on the limbs of a tree. Its markings so closely resemble the surrounding vegetation that it can very stealthily come upon its prey.

The plants on the savannas are largely tall grasses. During the rainy seasons the grasses begin to grow and acquire a height of several feet. During the dry seasons the grasses wither up and fall in broken masses to the ground. Few trees except scattered scraggly forms grow because they cannot withstand the long periods of drouth.

Land animals along the equator. Many of the animals in the dense rain forests live in treetops. Among these animals are monkeys, iguanas (ĭ-gwä′năz), boa constrictors, bright-colored birds, and many kinds of insects. These animals live in the trees because they can get food more readily than they can upon the ground. They live largely upon the green vegetation and in many cases upon one another. Most of the larger animals along the equator

A DROVE OF ELEPHANTS IN THE SAVANNAS



Ewing Galloway

Elephants are the largest land animals in the world. They are found only in Central Africa and in southern and southeastern Asia, where they graze on the tall grasses. In general, they are harmless and may be easily trained and domesticated.

live in the savannas, where the vegetation is not so dense. In the savannas of Africa, for example, we find such animals as the elephant, lion, leopard, hyena, hippopotamus, giraffe, antelope, and zebra. In the savannas of South America we find very few wild animals, the areas being used largely for grazing domestic cattle.

The foregoing discussion reveals that the rain forests and savannas abound with myriad forms of animal life. Some, such as the elephant, are very large; others, such as the lion, are ferocious; and still others, such as certain snakes, are deadly. Other animals, such as the monkey, are lively and playful, and some, such as certain birds, are extremely beautiful. All in all, then, the animals along the equator provide a very fertile field for study.

The hot damp conditions along the equator are especially favorable to the growth of insects. Among the most interesting are the termites, often called the white ants. These insects live in colonies organized according to a strict caste system. Each colony consists of a king and queen and

hundreds of soldiers and workers. The colony lives in a huge mound sometimes twenty feet high. The termites feed upon wood and do a great deal of damage, especially to buildings. Termites also infest buildings in the United States, but they are much more numerous and destructive in the tropics, where the temperature is higher and there is more moisture.

Plants and animals of the tropical sea. The tropical sea also possesses a variety of interesting forms of life. They occur because the direct rays of the sun and the warm water provide favorable conditions for growth. The plants consist largely of different forms of algae already mentioned, especially the brown sargassum. The animals include a great variety of forms, such as the shark, octopus, squid, coral, sea anemone, and a great variety of mollusks and crabs. Many of these animals are very unusual in size, shape, and color.

STRANGE INHABITANTS OF THE TROPICAL SEA

Matzdorf Animal Ecology and Ethology Chart—Courtesy A. J. Nystrom & Company

Here we see some of the interesting forms of life that abound in the tropical sea. Observe their many odd shapes and sizes. Some forms, such as the sea anemone and hermit crab, are interdependent, that is, they help one another.

Problem 7. Why are there so few forms of life near the poles?

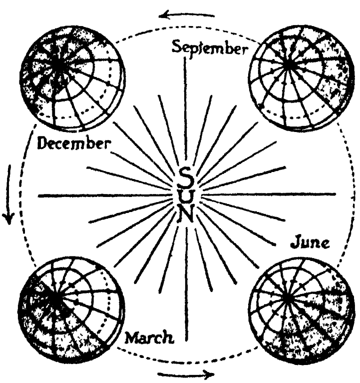
THE LIFE NEAR THE POLES

The area around the North Pole is largely water surrounded by land. It consists of the Arctic Ocean and northern lands in North America, Europe, and Asia. We may think of this area as a life region because it is not cut off by barriers. In fact, it may be said to belong to two realms, partly to the North American and partly to the Eurasian.

The area around the South Pole is different. This area consists of land surrounded by water. It includes the continent of Antarctica and the southern parts of the Atlantic, Pacific, and Indian oceans. We may think of this area as a realm because it is cut off from other areas by the oceans.

Plants and animals of the Arctic region differ greatly from those of the Antarctic realm. The differences may be traced largely to differences in geography and climate. One difference, already mentioned, is the fact that the Arctic consists largely of water and the Antarctic consists largely of land. The land surrounding the Arctic tends to give the area a varied climate. The Antarctic, on the other hand, has a uniformly frigid climate.

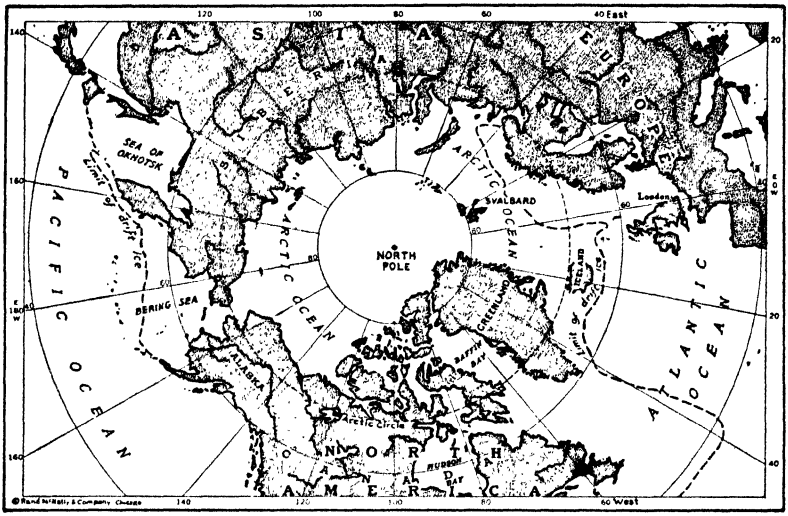
WHY SEASONS CHANGE AT THE POLES



In June the Arctic is having summer and almost continuous daylight. At this time the Antarctic is having winter and almost continuous darkness.

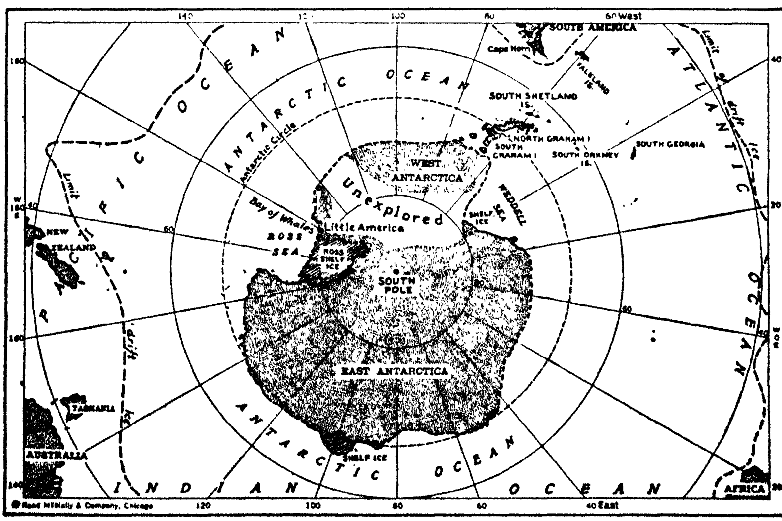
Summer in the Arctic comes when the North Pole is inclined toward the sun. During this time there is almost continuous daylight. The reverse conditions exist in the Antarctic. The South Pole is inclined away from the sun, causing winter and almost continuous darkness. When the South Pole is inclined toward the sun, the Antarctic has summer and the Arctic has winter.

AT THE TOP OF THE WORLD



The Arctic region is largely water surrounded by land.

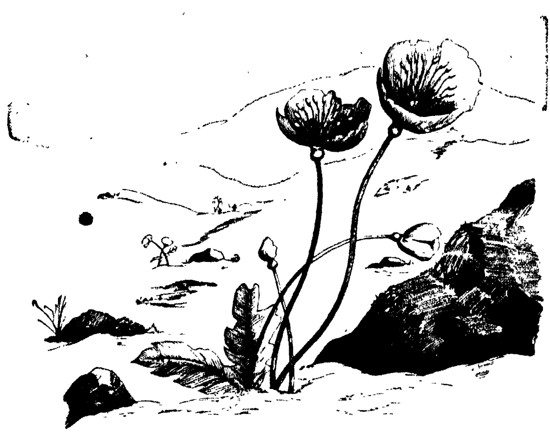
AT THE BOTTOM OF THE WORLD



The Antarctic realm is largely land surrounded by water. Compare this map with that shown above. How do the geographical differences explain differences in life forms?

At sea level the Arctic has an average temperature above freezing (32° Fahrenheit) during the summer. During the winter, however, the temperature may fall as low as 70° below zero. The average temperature of the Antarctic throughout the year is slightly colder than that of the Arctic. No month shows an average temperature as high as freezing.

A FLOWER OF THE NORTH—ARCTIC POPPY



This is a drawing of the Arctic poppy, which grows profusely in northern lands, even on the edge of snowbanks. Sometimes it is called the Iceland or the alpine poppy. Its large yellow flowers add great beauty to the barren environment.

Polar vegetation—the surprise of the Arctic. When summer comes in the Arctic, contrary to popular belief, many forms of plant life appear. The snow melts in places, and the ground thaws at the surface. The many hours of daylight and the warmer temperatures are very favorable to growth. Consequently, the ground may be frozen within a foot or so of the surface and at the same time be covered with ferns, mosses, lichens, and flowers. Some authorities say that the Arctic possesses as many as 28 species of ferns, 250 lichens, 332 mosses, and 762 flowering plants. The flowers on some of the plants grow very large, probably because of many hours of daylight. There are even a few trees in the Arctic, such as dwarf willows

and birches. Plant life in the Arctic is also profuse in the sea. So many green algae grow in the sea that it often looks green.

In contrast to the variety of vegetation in the Arctic, there are very few plants in the Antarctic. Here and there appear small patches of mosses, lichens, fungi, and algae, but no trees and no flowering plants. Therefore, on the whole, we may think of the Antarctic as a great barren waste, covered only with snow and ice.

Animal life of the Arctic. There are many forms of life in the Arctic, ranging in size from the large polar bear down to microscopic forms. These animals subsist partly upon vegetation and partly upon one another. Their chief adaptations are to certain kinds of food and to the very cold climate. In fact, they have become so strongly adapted to these conditions that it is difficult to take them to any other region.

When we think of Arctic animals, we think first, of course, of the polar bear. This animal ranges practically over the

THE POLAR BEAR WELL ADAPTED TO THE RIGORS OF THE ARCTIC

Courtesy Field Museum of Natural History

The polar bear thoroughly enjoys its very cold habitat. Its great strength and white color enable it to stalk its prey on land, and its ability to swim enables it to seize animals in the water. During the coldest months it hibernates under the snow.

entire region. It is very large, weighing nearly a thousand pounds, and has many interesting adaptations. Among these adaptations are its powerful front paws, white color, and cunning mind, all of which help it to secure food. Its chief food is seals, but it also eats birds and white whales and, occasionally, grasses, algae, and berries.

Another large interesting animal of the north polar region is the musk ox. Musk oxen look much like cattle. They are definitely land animals and feed largely upon grasses and dwarf willows. They stay in the north even in the winter, and have but one enemy, the wolf. They protect their calves by forming a circle around them and fighting off the wolf with their horns.

There are many reindeer or caribou in the Arctic, at least nine different species being known. The reindeer are land animals. They eat grasses, willows, mosses, and lichens. During the winter they dig into the snow and search for food on the ground. Many reindeer have been domesticated and

A HERD OF REINDEER IN THE NORTH

Ewing Galloway

This picture shows one of many herds of reindeer that may be found in far northern lands, especially in certain parts of Alaska. The natives raise the reindeer for commercial purposes, many of the animals being shipped to the United States for both food and hides. The reindeer live easily on the scanty Arctic vegetation.

OTHER RESIDENTS OF THE ARCTIC

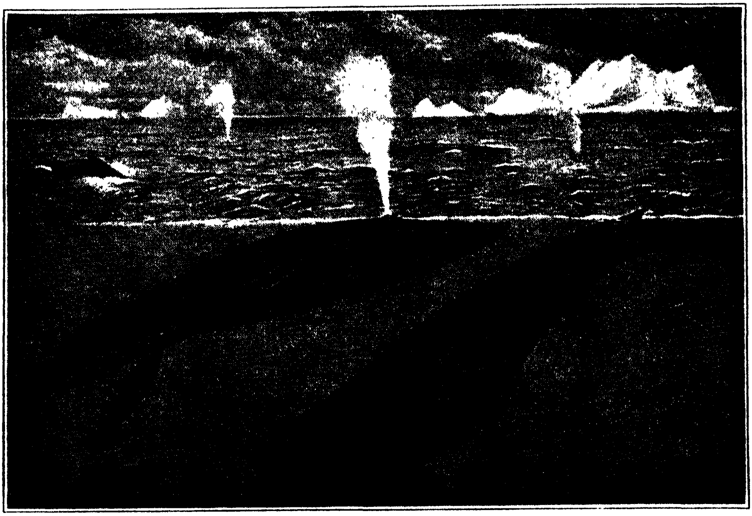
Seals are well adapted to life in the water, but at one time their ancestors probably lived on the land. The front limbs of the ancestors have been modified into flippers, and the hind ones into a tail. Seals may be trained to do many tricks.

are now being raised by the Eskimos and other people in northern Canada and Alaska. The reindeer are sold for food, much of it coming to the United States.

Other animals in the Arctic are the walrus, whale, seal, fox, and white hare. The walrus, whale, and seal are water animals. The fox and white hare, of course, are land animals. The natives catch a great many of these animals for food, oil, and clothing. People from other parts of the world also catch many of them, especially whales and seals, finding such hunting a very profitable business. All polar animals have interesting adaptations to their very cold environment.

Many birds thrive in the Arctic, the sea birds being more numerous than the land birds. Most of the land birds are migratory, staying in the Arctic only during the summer. Two exceptions are the snowy owl and the ptarmigan (tär′mĭ-găn), which stay all winter long. Among the migrating land birds are the raven, the purple sandpiper, and the snow bunting. The sea birds include the wild goose, eider

WHALES OF THE SOUTH POLAR REALM



Courtesy Quelle und Meyer

Although whales live in the water, they come to the surface to breathe. At one time, however, they can take in enough air to last about an hour. Just before they inhale, they always expel the old air from their lungs, sending up a spray known as a spout.

duck, Arctic tern, auk, loon, and gull. Most of these birds build their nests in sheltered cliffs along the shore.

One of the surprising features of the Arctic fauna is its number of insects. Great swarms of mosquitoes appear during the summer. Bumblebees, gnats, and butterflies also find the Arctic a very pleasant habitat.

Animal life of the Antarctic. Generally speaking, the animals of the Antarctic are water animals, the only exceptions being such insignificant forms as wingless insects. The water animals are fairly abundant. The most important are seals and whales, of which there are numerous species. Most of the birds, with the exception of the penguin, are migratory. The penguin stays all year round and is well adapted to its environment. It walks upright and in the distance has the appearance of a short fat man dressed in evening clothes. It swims and dives in search of food, living largely upon smaller forms of marine life. Another condition favorable to its

PROUD INHABITANTS OF THE ANTARCTIC

Courtesy American Museum of Natural History

At a distance penguins look like short men walking about in dress suits. They stand nearly upright, but never fly, using their short flipper-like wings only for swimming. Admiral Byrd on his expeditions to Antarctica found them very interesting birds.

growth is the absence of enemies. It can swim during the summer or waddle over the ice during the winter without danger. Thus it gives a fantastic touch to land that is otherwise a great barren waste.

Problem 8. Why do certain islands have peculiar forms of life?

ISLAND FLORA AND FAUNA

The water which surrounds islands constitutes a barrier even more definitely impassable than mountain ranges or other barriers on continents. Land plants and land animals stranded on island areas cannot escape from their island homes. Thus plants and animals stranded on islands in the far-distant past have developed into forms that in some instances are unique. This is especially true of islands far removed from the larger land areas like the Americas, Eurasia, and Africa. Most of

the unique forms are found in Australia, which in a sense is a very large island, and in Tasmania, New Zealand, the Galápagos (gä-lä′pä-gôs) Islands, and other smaller islands in the same general part of the world.

The plant life of Australia. The island continent of Australia provides a variety of environments including tropical jungles, deserts, fertile land areas, seasonal river valleys, and mountains. The interior of the country is semiarid, but near the shore the conditions are more favorable to growth. Wheat, sugar cane, and fruits are grown so extensively in some parts that they play an important part in world trade. All in all, then, Australia offers a wide variety of habitats.

People often think of Australia as a treeless country, but such is not the case. As a matter of fact, the country contains many trees, some of them having made interesting adaptations to the dry environment. The she-oak, for example, has no leaves, and the ti-shrub has only needles. The bottle tree has a short, thick trunk with very little foliage. Some of the trees, where there is more moisture, are very tall, among them being the gum tree—one of the tallest trees in the world. Altogether, then, the trees have a wide variety of sizes and shapes.

THE BOTTLE TREE

Courtesy D. S. Wylie

Notice how closely the trunk of this tree resembles a real bottle. Often the trunk is only a hollow shell, being open on the inside somewhat like a barrel.

The most important tree of Australia is the *Eucalyptus* (ū′kȧ-lĭp′tŭs), tree, of which there are more than three hundred species. Usually it grows very tall and has a beautiful

A TROPICAL JUNGLE IN AUSTRALIA

Courtesy Australian Commonwealth Development and Migration Commission

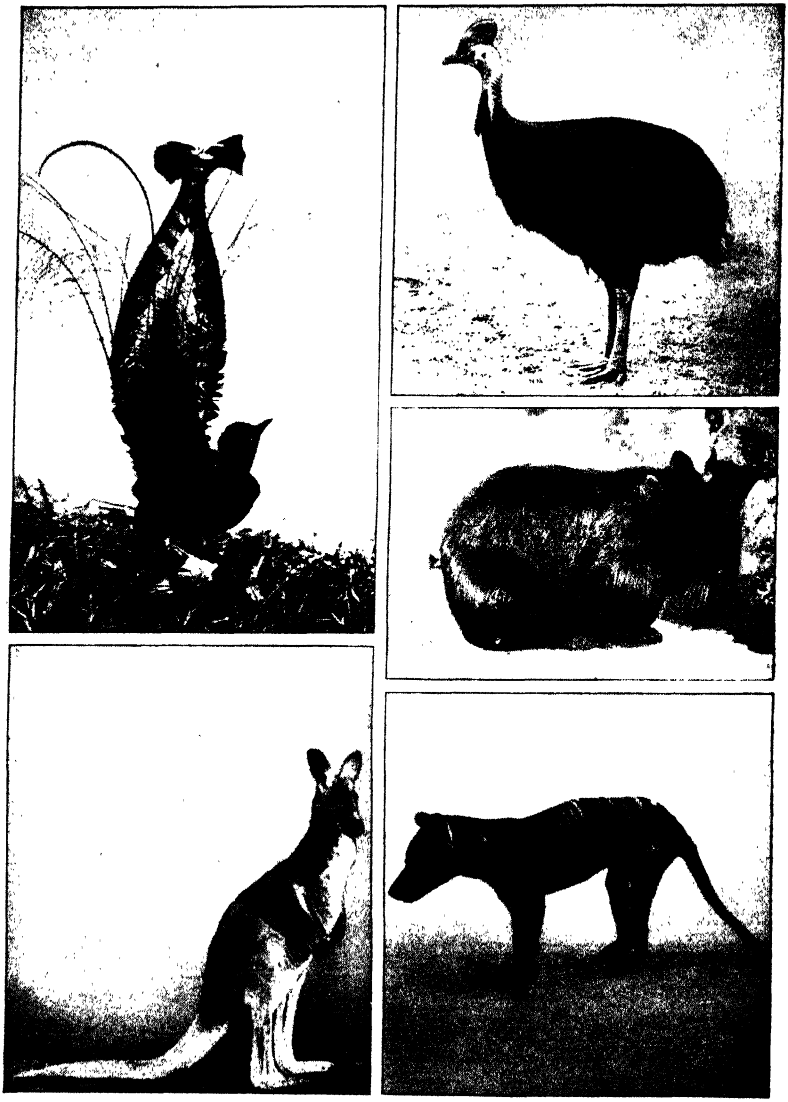
This picture shows some of the tangled growths (lianas), tree ferns, and giant trees that abound in the jungle areas along the coast in the northeastern part of Australia.

appearance. Some species growing in the regions of high rainfall reach a height of over three hundred feet. Their leaves have made a striking adaptation in that the edges turn skyward as a protection from the sun. The second tree of importance in Australia is the *Acacia* (*ȧ*-kā′sh*ȧ*). This tree, which is smaller than the Eucalyptus, lives in the semidesert areas of the central and west-central parts. Dense thickets of Acacia in the more arid regions are known as mulga.

Along the coast, in the northeastern part of Australia, are small areas of jungle similar to those along the equator in South America and Africa. Here we find the Eucalyptus and other trees peculiar to Australia; tree ferns, bamboos, and palms; and large woody vines called *lianas* (lē-ä′n*ȧ*z). All this vegetation together forms a very dense tangle.

Odd animals of Australia. On the whole, the animal life of Australia is very peculiar. Some forms of life, such as the

ODD ANIMALS OF AUSTRALIA



This picture shows some of the odd animals to be found in Australia. From left to right at the top are two birds, a lyre bird and a cassowary. Below the cassowary is an animal known as a wombat. From left to right at the bottom are a kangaroo and a Tasmanian wolf.

kangaroo, the wombat, and the Tasmanian wolf, are found in no other parts of the world. All these animals have the interesting adaptation of an external pouch in which they carry their young. The kangaroo has powerful hind legs and a very large tail, which enable it to hop rapidly from place to place. The wombat looks somewhat like a small bear, but at the same time has many of the characteristics of rodents. The Tasmanian wolf somewhat resembles the American wolf but is in no way related. It is very destructive and kills a great many sheep.

Other peculiar animals of the Australian realm are the duckbill and the echidna (ē-kĭd′nȧ), fur-covered animals that lay eggs. Besides these strange creatures, there are many interesting birds, such as the giant moa, bird of paradise, emu, cassowary, and lyre bird. In near-by water we also find some of the largest coral colonies of the world. Along the eastern coast are great reefs built from the skeletons of coral.

Unique animals of the Galápagos Islands. The effects of isolation are strikingly illustrated by the unique animals on the Galápagos Islands. These islands are situated along the equator, in the Pacific ocean about five hundred miles west of South America, far from other land areas in the world. It has been estimated that 37 per cent of the shore fish, 40 per cent of the plants, and 96 per cent of the reptiles belong to these islands alone. Members of a recent scientific expedition brought back fifty-two species of moths which have never been found in any other part of the world. Other interesting forms of life are sea lions, lizards, giant tortoises, flamingos, and cormorants.

Problem 9. How may the distribution of living things be summarized?

All forms of life depend greatly upon their environment. They make adaptations or adjustments that enable them to utilize conditions of their environment. Every form of life has a *habitat,* or home, where it can live best. The conditions of the habitat are controlled largely by such factors as tempera-

ture, moisture, light, and food supply. Habitats of the same forms of life are scattered over large areas known as a *range.* The range of the robin, for example, extends from Mexico to Alaska. There are numerous places or habitats within this range where the robin can live. The conditions in each of these places are essentially the same.

The conditions favorable to one form of life are often favorable to certain other forms. Therefore numerous forms of life live in the same area—or, in other words, have a common range. Such a common range is known as a *life zone.* The United States, for example, has many life zones brought about by variations in geography and climate. The forms of life in neighboring zones are often somewhat similar. This, again, is because of fairly similar conditions. A group of neighboring life zones make up an area known as a *region.* Neighboring regions are sometimes cut off from other regions by impassable barriers, such as oceans. A group of regions cut off from other groups is known as a *realm.* Altogether there are eight major realms in the world. Since living things cannot pass back and forth from one realm to another, each realm has life forms peculiar to itself.

Up to this point in the study of biology, we have briefly considered the distribution of living things upon the earth. We have noted forms of life with which we are thoroughly familiar and how they have adapted themselves to the conditions of winter and summer. We have visited fresh-water streams, ponds, and lakes and noted how thousands of plants and animals have adapted themselves to such factors of environment as temperature, oxygen, and impurities. We have learned how life forms in the mountains have adjusted themselves to the rugged environment, the extreme changes in temperature, and the heavy winds. We have noted how cactus plants and camels, along with other plants and animals of the desert, have developed the ability to live with little water. We have visited the depths of the sea, the tropics, the areas around the poles, as well as several islands, and noted many interesting forms of life, both plant and animal.

As we considered the distribution of life forms, we found that everywhere they are adapted to the conditions of environment. Plants and animals in each area have developed certain distinguishing characteristics that enable them to utilize the conditions around them. The character of adaptations to varying geographical and climatic factors explains why forms of life are so widely and definitely distributed.

Problem 10. What sciences help us in a study of living things?

BIOLOGY AND RELATED SCIENCES

Now that we have briefly explored the world for living things, we have a better idea of the vast number of life forms and their wide distribution. We are now ready for a more detailed study of living organisms from such standpoints as origin, development, structure, and function. These and related topics include the civic and economic problems which may be solved by the science of biology.

With at least a million species of plants and animals to study, biology covers a very broad field. In order to understand its real scope, it is necessary to know a little about the sciences of which it is composed or to which it is closely related. The most important of these sciences may be defined as follows:

a. *Botany* (bŏt′ȧ-nĭ) is the science which deals with all phases of plant life.

b. *Zoölogy* (zō̇-ŏl′ō̇-jĭ) is the science which deals with all phases of animal life.

c. *Anatomy* (ȧ-năt′ō̇-mĭ) is the study of the structure of organisms.

d. *Physiology* (fĭz-ĭ-ŏl′ō̇-jĭ) is the study of the functions of the various parts of organisms.

e. *Hygiene* (hī′jĭ-ēn) is the study of the care of an organism for the preservation of its health.

f. *Bacteriology* (băk-tē̇-rĭ-ŏl′ō̇-jĭ) is the study of certain one-celled plants called bacteria.

g. Sanitation (săn-ĭ-tā′shŭn) is the science of promoting health through cleanliness in the environment.

h. Pathology (pă-thŏl′ō-jĭ) is the study of disease and the effects of disease upon the body.

i. Embryology (ĕm-brĭ-ŏl′ō-jĭ) is the study of the development of organisms from fertilization to birth.

j. Paleontology (pā′lē-ŏn-tŏl′ō-jĭ) is a study of the origin of plants and animals as shown by fossil records.

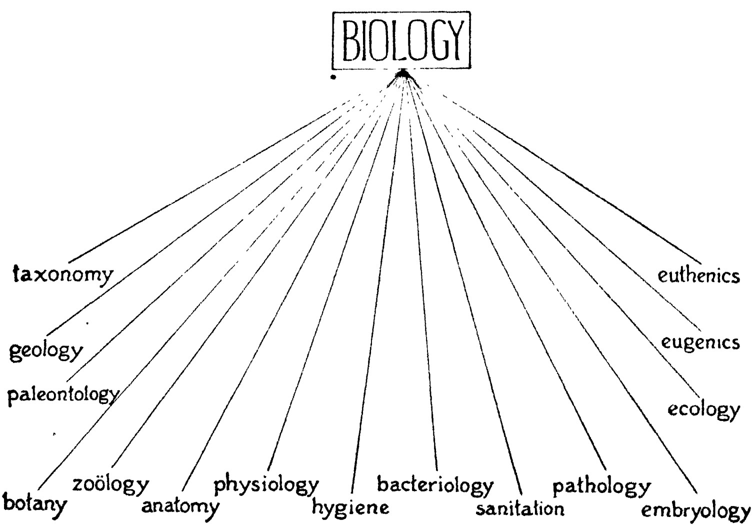
k. Geology (jē-ŏl′ō-jĭ) is the science which treats of the earth and its life as recorded in the rocks.

l. Taxonomy (tăk-sŏn′ō-mĭ) is the science dealing with the classification and naming of organisms.

m. Eugenics (ū-jĕn′ĭks) is the science dealing with the improvement of the human race through the application of the laws of heredity.

n. Euthenics (ū-thĕn′ĭks) is the science dealing with the improvement of environment so that its influence upon mankind will be more desirable.

o. Ecology (ē-kŏl′ō-jĭ) is the study of the relation of organisms to their environment.



SUGGESTED ACTIVITIES

I. Self-Organization Summary

Before you proceed to the next unit, you doubtless will wish to organize systematically what you have learned. The following exercises have been designed to help you accomplish this purpose. In order to derive the greatest good from their use, you may wish to write the answers in your biology notebook. This will enable you to preserve a condensation of important facts and principles. By the end of the year you should have a well-organized summary of the book as a whole.

THE DISTRIBUTION OF ORGANISMS

A. Explain and illustrate each of the following terms which you have found in this unit:

1. Environment
2. Habitat
3. Range
4. Zone
5. Region
6. Realm

B. Locate the important life zones of the United States and mention a few forms of life found in each.

C. Locate the realms of the world and show how they are broken up into regions. Give examples of the plants and animals found in the various regions.

D. Describe each of the following places from the standpoint of its environmental conditions and its flora and fauna:

1. Fresh-water streams and ponds
2. High mountains
3. Deserts
4. Ocean depths
5. Tropics
6. Polar regions
7. Islands

E. State your understanding of the scope of biology and each of the related sciences discussed in this unit.

II. Display Posters

A. Make a collection of pictures of the plants and animals of each of the seven places discussed in this unit. The visual aids listed on pages 59–61 will give you ideas on the subject. You will be able to secure good pictures from magazines and advertising booklets.

B. Prepare maps of the life zones of the United States and Eurasia and show some of the life forms in each. The maps of life regions and zones will guide you. You should not, however, copy these maps or limit your illustrations to those in the book.

III. Special Reports

A. Working with your classmates, organize imaginary exploring parties for the purpose of taking trips into some of the realms of the world. Decide which realms you wish to visit and what you will need for the trips. Finally, gather as much information as you can about the realms and give reports to the class as if your trips were real. The following references, as well as many advertising folders of railroad and steamship companies, will provide valuable information for carrying out the project.

REFERENCES

The following list of references will help you to expand your understanding of the distribution of life forms. The names of all books, except reference sets, are given after the names of their authors. This arrangement will enable you to find books readily if your library is cataloged in the usual manner. Titles of chapters or units and page numbers are given to enable you to turn to the desired pages as quickly as possible. A complete list of authors, books, and publishers, including the references for all units, is given in the Appendix on pages 694–698.

1. Barrows, William M. *Science of Animal Life.*
   a. Aquatic associations, pp. 311–320
   b. Deep-sea life, pp. 311–320
   c. Intestinal parasites, pp. 181–197
2. Beebe, Charles William. *Half-mile Down.*
   a. A wonderful undersea, pp. 3–20
   b. Proto-bathyspheres, pp. 42–66
   c. A descent into perpetual night, pp. 181–227
3. Beebe, Charles William. *Jungle Days.*
4. Brown, R. N. Rudmose. *The Polar Regions.*
   a. Polar climates, pp. 33–47
   b. Polar vegetation, pp. 112–125
   c. Arctic animal life, pp. 126–137
   d. Antarctic animal life, pp. 138–145
5. Byrd, Richard E. *Little America.*
6. Clark, Austin Hobart. *Animals of Land and Sea.*
   a. Fresh-water animals, pp. 202–216
   b. Deep-sea animals, pp. 186–194

7. Hardy, M. E. *Geography of Plants.*
8. Newbigin, Marion I. *Animal Geography.*
9. Park, William H., and Williams, Anna W. *Who's Who among the Microbes.*
10. Siple, Paul. *A Boy Scout with Byrd.*
    a. Seals, p. 114
    b. Penguins, p. 126
11. Tarr, Ralph Stockman, and Von Engeln, O. D. *New Physical Geography.*
    a. Distribution of plants, pp. 529–543
12. Ward, Henry B., and Whipple, George C. *Manual of Fresh-Water Biology.*
    a. Conditions of existence of fresh-water life, pp. 21–59
    b. Fresh-water algae, pp. 115–125
13. *Book of Popular Science, The.*
    a. Desert regions and their life, Vol. 12, pp. 4155–4165
    b. The story of polar seals, Vol. 8, pp. 2623–2631
14. *Compton's Pictured Encyclopedia.*
    a. An outline of biology, Vol. 2, pp. 116–118
    b. Exploring ocean depths, Vol. 10, pp. 195–201
15. *New Wonder World, The.*
    a. Life goes everywhere, Vol. 10, pp. 1–9
    b. Living lamps (phosphorescent animals), Vol. 10, pp. 237–239
16. *World Book Encyclopedia, The.*
    a. The story of polar explorations, pp. 5691–5699
    b. The distribution of animals—outline, Reading and Study Guide, pp. 8487–8490

The *Encyclopedia Americana*, the *Encyclopaedia Britannica*, and the *New International Encyclopedia* contain excellent materials which are a bit more difficult than those in most of the other references. If one of these sets is available, it should be used in connection with the study of each of the units in this book. Topic and page references are not given, since the sets are alphabetized and consequently are easy to use.

VISUAL AIDS

Few subjects are more dependent upon visual aids for a proper understanding of facts and principles than is biology. This book is richly illustrated with pictures and drawings to help tell the

story. All these illustrations should be considered a definite part of the content, for they supplement the reading context and sometimes contain as much information as three or four pages of the context alone.

Regardless of how many illustrations there are in a book, students are always eager to examine others of an interesting nature. Among the more valuable visual aids in the field of biology are lantern-slide projections and motion pictures. Lantern slides are not listed here, since they usually come in sets and consequently there is no need of naming them. For example, any school may secure from standard slide companies sets covering different topics discussed in this unit. On the following page is a list of films suitable for showing with the work of this unit.

In both large and small high schools, student operators can handle lantern-slide projectors and motion-picture machines satisfactorily and economically. Your teacher will have no difficulty in working out a plan for such a procedure. If you are fortunate enough to be selected as one of the operators, you will derive additional pleasure from your study of lantern-slide and film material.

Charts[1]

C. Region of the Deep Sea

1. Meinhold Zoölogical	Crabs, Shrimp, etc.
2. Meinhold Zoölogical	Octopus, Squid, etc.
3. Meinhold Zoölogical	Sea Horses, Hydra, etc.
4. Meinhold Zoölogical	Corals, Sponges
5. Meinhold Zoölogical	Starfish, etc.
6. Meinhold Zoölogical	Jellyfish, Anemone

D. Tropical Jungles

1. Tauber Geographic	Virgin Forest of Sumatra

E. Polar Regions and Their Life

1. Tauber Geographic	Life in the Antarctic

[1]The charts listed here have been selected because they correlate well with the materials in the unit. Such names as Meinhold or Tauber refer to standard titles of certain sets of charts. These sets may be secured from several of the leading chart and map companies.

A. LIFE ON HIGH MOUNTAINS

1. Tauber Geographic	North American Pine Forest
2. Tauber Geographic	North American Rocky Mountains
3. Tauber Geographic	Himalaya Mountains

B. LIFE OF THE DESERT

1. Tauber Geographic	The Sahara Desert

F. ISLAND FAUNA AND FLORA

1. Tauber Geographic	Virgin Forest of Southeastern Australia
2. Tauber Geographic	Eucalyptus Forest in South Australia
3. Tauber Geographic	Scrub Region in West Australia

FILMS (16 mm.)

A. The Y. M. C. A. Motion Picture Bureau, 347 Madison Avenue, New York City, or 19 South La Salle Street, Chicago, Illinois.
  1. Down at Our Pond. 1 reel, silent, $1.50 per day.
  2. Top o' the World (Canadian Rockies). 1 reel, silent. Free.
  3. To the South Pole with Byrd. 1 reel, silent. Free.
  4. Re-conquering Antarctica. 3 reels, sound. Free.

B. Indiana University, Extension Division, Bloomington, Indiana.
  1. Undersea Life. 1 reel, silent, $1.00 per day.
  2. Dwellers of the Deep. 1 reel, silent, $1.00 per day.

C. Herman A. DeVry, Inc., 111 Center Street, Chicago, Illinois.
  1. How Living Things Find a Home on the Earth. 1 reel, silent, $24.00.
     Develops the theme of adaptation to the environment

D. University of California, Extension Division, Berkeley, California.
  1. Wild Life on the Desert. 1 reel, silent, $1.00 per day.

UNIT TWO

THE FASCINATION OF MICROSCOPIC LIFE

SUGGESTIONS TO THE TEACHER

The study of biology depends greatly upon the microscope. This important instrument enables us not only to look at countless forms of life too small to be seen by the naked eye, but also to study the structure of larger forms of life. Indeed, it means more to biology and all its different divisions, such as bacteriology, botany, zoölogy, and anatomy, than does any other instrument. With its help, workers in these various fields have greatly extended the bounds of knowledge and have brought about a more complete mastery of nature.

The purpose of this unit, of course, is not to study the structural details of plants and animals, but rather to catch a glimpse of the countless invisible forms of life that abound in the immediate environment. Such a glimpse will help the student to realize that on a trip to a weedy pond or ditch he may find millions of microscopic creatures more varied than the larger forms of life that he readily sees in the environment.

It is important to have each student practice with the microscope and the materials at hand until he can manipulate both with ease. He may then approach with confidence the problems of exploring microscopic materials.

OBJECTIVES

I. Facts and principles

A. To explore a few of the varied flora and fauna of microscopic life

B. To learn the characteristics, habits, and classifications of important typical forms

C. To develop a technique in the use of the microscope through the exploration of these forms

D. To learn more about cell structure and the work done by cells

II. Attitudes

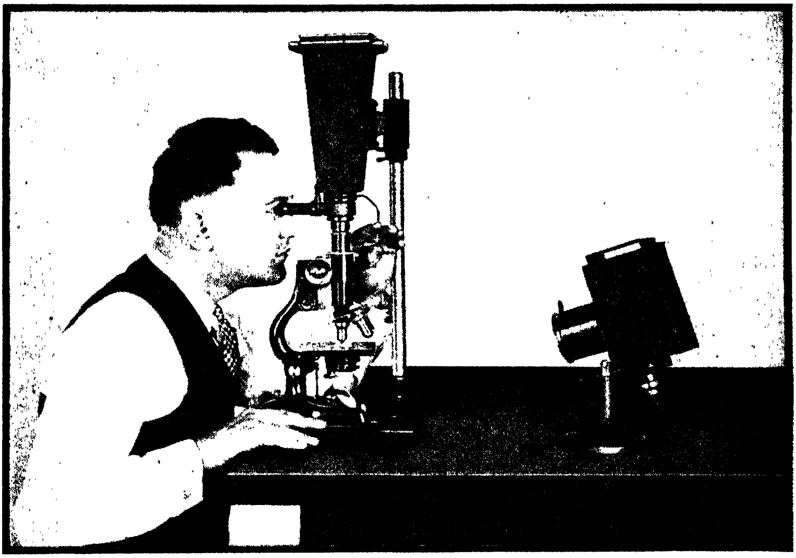
A. To develop an appreciation of the vastness and beauty of microscopic life

B. To build up an understanding of the economic value of microscopic life

UNIT TWO

THE FASCINATION OF MICROSCOPIC LIFE

MAKING SNAPSHOTS OF GERMS



Courtesy Bausch & Lomb Optical Company

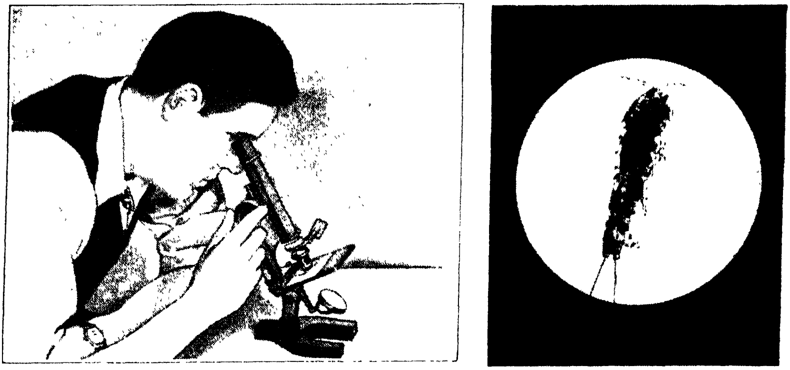
Have you ever wondered how bacteria, protozoans, and other invisible forms of life have their pictures taken? The pictures are taken by a photomicrographic camera, shown at the left. The instrument at the right merely throws a light on the mirror below the specimens.

DAN EISLER AND HIS MICROSCOPE

PREVIEW

Would you be interested in hearing what Dan Eisler, a student like you, accomplished with a microscope? From the first moment when Dan peered through a microscope in a high-school laboratory, he became so interested in microscopic forms of life that he made microscopic work a hobby. With the help of his father, he set up a small laboratory at home.

DAN AT HIS MICROSCOPE AND WHAT HE SAW



The microscopic animal at the right is a cyclops.

He procured a small microscope and various microscopic supplies. He also obtained a number of books on the subject of microscopy (mī-krŏs'kō-pĭ) and learned the technique of carrying on the work.

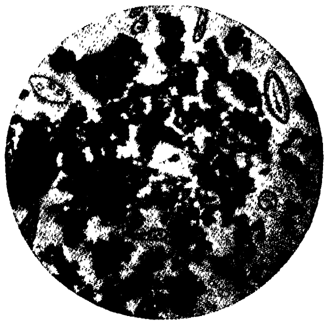
Finally Dan took a hike along a sluggish woodland stream to look for specimens. He was eager to examine under his own microscope some of the plants and animals that he had read about in books. How proud he was to find that his observations were similar to those of many noted scientists! After he had mastered the fundamental steps in microscopy, he conducted several experiments of his own and carefully recorded his findings. In the end, he did such important work that he brought nation-wide recognition both to himself and to his school.

It was through the National Association for the Advancement of Science that Dan's discoveries received attention. This association sponsored a contest among high-school and college students throughout the United States. Hundreds of manuscripts were submitted, including a paper by Dan entitled, "Experiments with Diatoms" (dī'ȧ-tŏmz).[1] Imagine Dan's joy a few weeks later when the results were announced and his paper was given second place among all those submitted. He

[1] These discoveries had to do with methods of washing diatoms preliminary to making photomicrographs.

felt the satisfaction that comes through the achievement of an outstanding piece of work. More than that, he found an excellent way of spending his leisure time. The following extract from his prize-winning paper reveals some of the enthusiasm that he felt:

WHAT A DROP OF POND WATER REVEALED



Courtesy *Book of Popular Science* by permission of the Grolier Society

This illustration shows a drop of water from a pond as it appears under the microscope. Several protozoans (one-celled animals) are swimming about among the bits of decayed vegetation in the water.

From the eventful moment in my life when I peered awkwardly through a high-powered microscope at the hundreds of tiny plants and animals in a single drop of pond water, I became imbued with the idea that I must have a microscope, and that I must grope with "fog-filled" brain to unravel some of the mysteries of the life around me.

Why do I say "fog-filled"? It soon became evident to me that I was seeing but one tiny section of creation, and *that* under high magnification. Finally it dawned upon me how many are the unseen inhabitants of our environment.

The more I experimented, the more enthusiastic I became. I could scarcely tear myself away from my laboratory table. The hours spent at the microscope I count as golden hours. Each new drop of water held a fascination which far outweighed the interest I had in any other activity.

The problems below will help you to realize how Dan felt as he looked at the world through a microscope.

PROBLEMS

1. **How was the modern microscope perfected?**
2. **What should we know of the modern microscope in order to operate it successfully?**
3. **What does the microscope show us about cells and cell structures?**
4. **What hidden forms of life are revealed by the microscope?**

Problem 1. How was the modern microscope perfected?

The world of microscopic organisms long existed, unseen and unknown to man. Its millions of inhabitants were discovered only a comparatively short time ago in the history of man. Indeed, microörganisms (mī'krô-ôr'găn-ĭz'mz)[1] remained completely hidden until the invention of the microscope.

EARLY THEORIES OF INVISIBLE LIFE

The menace of the invisible world. Many theories were advanced in early times about the causes of disease. Many scientists thought that disease came from a living poison or virus. About two thousand years ago, however, scientists began to form a vague notion that disease was caused by tiny organisms that found their way into the body. Even so, as late as the middle of the nineteenth century, disease was still shrouded in a great deal of mystery. A real menace existed—millions of lives were sacrificed because of ignorance of unseen foes.

What the ancients believed about disease. People in early times often associated disease with gods or devils. They commonly thought that disease was sent as a punishment. We can readily understand why they had such beliefs, for they had no real scientific equipment, such as the microscope. Moreover, they were constantly faced with the menace of the unknown through such diseases as smallpox, cholera, and black death. In addition, they were often visited by others that destroyed both animals and crops.

A beam penetrates the unknown—the first lenses. In 1590 Janssen, a manufacturer of lenses, began working with imperfectly ground, low-magnification lenses. Kircher, a monk, in 1659 followed with lenses that were somewhat improved. Although these early lenses had no great power of magnification, yet they possessed enough to arouse the curiosity of Anthony van Leeuwenhoek (lā'vĕn-hŏŏk), a Dutch glass worker.

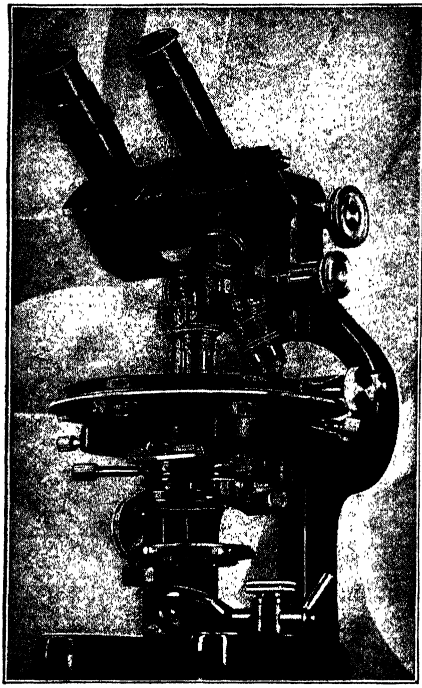
[1]**Microörganisms—organisms that can be seen only under the microscope.**

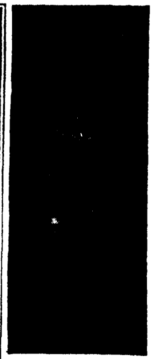
ANTHONY VAN LEEUWENHOEK AND HIS MICROSCOPE

Painted especially for the Bausch & Lomb Optical Company by W. F. Soare
Courtesy Almer Coe & Company

This picture shows Leeuwenhoek explaining his discovery of bacteria by the use of a simple combination of lenses, the forerunner of the modern microscope.

A MODERN MICROSCOPE IN CONTRAST WITH THAT OF LEEUWENHOEK





Courtesy Bausch & Lomb Optical Company

With Leeuwenhoek's invention it was necessary in focusing to move the object nearer to or farther from the lens. With the modern microscope the objective lenses are moved, but not the object. Comparing these two microscopes, what improvements would you say have been made?

Leeuwenhoek had a great desire to look at the invisible world to find out what it was like. He believed he could make lenses better than any that had yet been produced. Accordingly, in 1675, he produced lenses that enabled him to magnify objects that had never been seen before. At first he examined only large objects, such as bee stingers, hairs, sections of wood, and the like. He was so inspired by this type of research that he soon began to experiment with a combination of lenses. Finally, after years of experimentation, he brought about the invention of the first workable microscope. As a result of this notable achievement, he has come to be known as the "father of microscopy."

The microbes become visible—the perfection of the microscope. The finest microscopes of today, capable of magnifying three thousand diameters, are but a logical development of Leeuwenhoek's simple seventeenth-century device. Leeuwenhoek's problem was not alone that of perfecting lenses, but also that of finding out how to separate metals from ores and how to mold metal into plates and hollow tubes. Lenses and metal

plates and tubes were all needed in constructing a compound microscope. With his first crude device Leeuwenhoek brought into focus a new world, and then set about the task of improving his instruments. It is said that he collected 274 microscopes during the time he was engaged in his memorable work.

For two hundred years following the death of Leeuwenhoek very little was done to improve the compound microscope. During the last half-century, however, so much has been done that today it is considered one of the most important instruments of scientific research.

In the Army Medical Museum in Washington is a collection of microscopes some of which date back to the time of Janssen and Leeuwenhoek. This interesting collection shows the progressive steps that have been taken in bringing about the highly complicated and effective instrument we have today.

Problem 2. What should we know of the modern microscope in order to operate it successfully?

To enjoy a microscope to the fullest extent, we must become thoroughly acquainted with its parts and learn how to operate it. Since it is a delicate and expensive piece of apparatus, it must be handled very carefully. This makes it all the more necessary that we have training in its use.

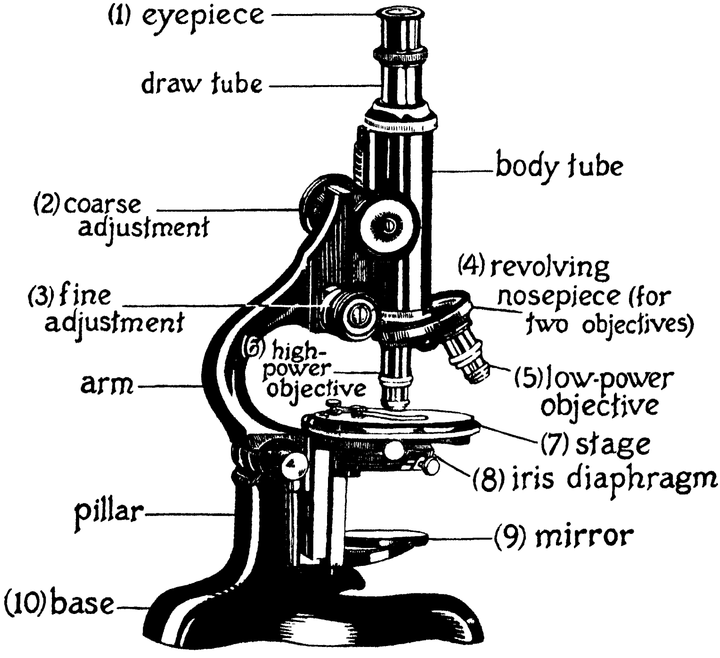
THE COMPOUND MICROSCOPE

Parts of the microscope. The microscope most generally used in school work is a compound microscope. This instrument has a combination of lenses permanently mounted in relation to one another. One set of lenses—the objective—forms an enlarged image of the object to be studied. This image is further enlarged by another set of lenses—the eyepiece—which is next to the eye of the observer. The diagram on the following page shows where the lenses are located.

The parts of the microscope explained. (1) The *eyepiece* is the tube that contains the set of lenses nearest the eye of the observer. (2) The *coarse adjustment* consists of two large wheels

which the observer uses to raise or lower the objective when he is trying to locate the specimen to be examined. (3) The *fine adjustment* consists of two smaller wheels which the observer

THE COMPOUND MICROSCOPE



Standard microscopes for high-school use are now equipped with low- and high-power objectives. The lenses of the objectives and eyepieces (oculars) are made from specially manufactured optical glass. It is the cost involved in grinding these delicate lenses that makes a microscope expensive. Great care should be taken in cleaning microscope lenses lest they become scratched. Special lens paper of a soft, silky texture is prepared for this purpose.

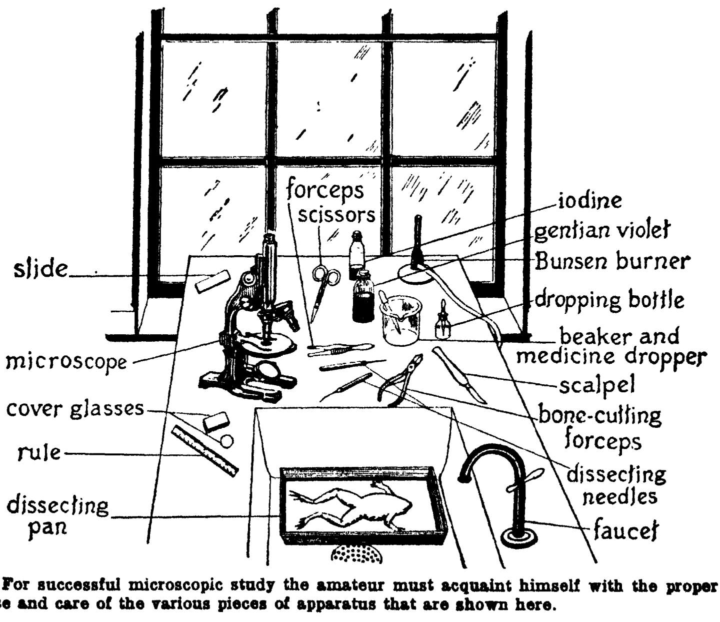
uses to raise or lower the objective slightly so as to make the specimen more distinct. (4) The *revolving nosepiece* is the part the observer turns to change from one objective to another. (5) The *low-power objective,* usually the shorter, is the one having the low power of magnification. (6) The *high-power objective* is the one having the high power of magnification. (7) The *stage* is the platform on which the slide is placed. (8) The *iris*

diaphragm regulates the amount of light admitted to the object. (9) The *mirror*, which is attached to a movable arm under the stage, reflects the light through the object and lens to the eye of the observer. (10) The *base* is the heavy part that anchors the microscope to the table.

How to Do Microscopic Work

Now that we are acquainted with the parts of the microscope, we should be able to follow instructions in its use. The procedure must be mastered if we are to succeed in carrying out the various laboratory exercises in the course.

EQUIPMENT USED IN MICROSCOPIC STUDY



For successful microscopic study the amateur must acquaint himself with the proper use and care of the various pieces of apparatus that are shown here.

A. How to prepare a slide for study

1. Wash the slide and cover glass. Be careful in handling them, for they are very thin and will readily break. A good method is to place them gently on blotting paper and wipe them while they lie flat on the surface.

2. In making sections for study, use a razor or a very sharp knife. The material to be examined must be thin, because the light must pass through it. For making a close study of certain plant or animal parts, dyes or stains, such as eosin (red ink), safranin, gentian violet, or iodine, may be used to make the details stand out better. Consult your teacher for specific directions.

3. Place the material in the center of the slide. Cover it with a drop or two of clear water or glycerin.

4. Carefully place the cover glass over the material so that no liquid will get on the upper surface of the cover glass.

If you have made the slide according to directions, you are now ready to examine it with the microscope, observing the following instructions.

B. Focusing

1. Be sure that the lenses in the eyepiece and objective are clean. If necessary, wipe them with a clean piece of lens paper.

2. Move the low-power objective (the shorter one) until it snaps into position under the tube of the microscope.

3. Look through the eyepiece and shift the mirror until it reflects the light rays up through the object. Be careful to keep the mirror away from the direct rays of the sun. Reflected light from white clouds is best.

4. Place the slide on the stage with the material directly under the objective.

5. Turn the coarse-adjustment wheels forward, or away from you, to lower the low-power objective. Stop when the objective is about an eighth of an inch from the slide.

6. Look through the eyepiece and slowly turn the coarse-adjustment wheels backward, or toward you, to raise the low-power objective. Stop when the object comes into view. Then move the slide slowly about until you obtain the best sectional view of the specimen.

7. When you wish to study a specimen in considerable detail, use the high-power objective. Revolve the nosepiece until the high-power objective takes the place of the low-power

objective. Use the fine adjustment for focusing, turning the knob slightly forward or backward until you bring the object clearly into view.

8. Do not become discouraged if you should fail in your first attempts to use the microscope successfully. Merely be patient and keep trying until you secure satisfactory results. If you follow the instructions carefully, you will soon be thrilled with your ability to use such a fascinating instrument.

Problem 3. What does the microscope show us about cells and cell structures?

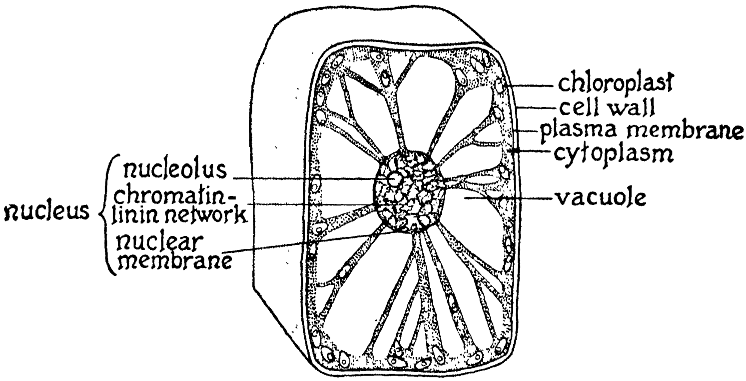
With the aid of the microscope we shall see that all living things are composed of tiny units of living matter called *cells.* When we examine under a microscope thin sections of any part of a plant, such as root, stem, leaf, flower, or fruit, we find that they are composed of cells. Similarly, blood and sections from the structure of an animal, such as skin, muscle, bone, and all other tissues, are composed of cells. Some plants and animals consist of but a single cell. Such a cell, even though it lives alone, performs all the fundamental functions necessary to sustain life. Later we shall study a few of the most common forms of single-celled plants and animals and observe how they perform the essential functions of life. In the many-celled or higher forms of living things, the functions of the cells become highly specialized according to the type of tissue of which they are a part.

PLANT AND ANIMAL CELLS

What cells are. A cell may be defined as a tiny mass of *protoplasm* surrounded by a *cell wall* or *membrane* and generally containing a *nucleus* (nū′klē̇-ŭs). Protoplasm, as we have learned, is the living matter in cells, the real living substance in both plants and animals. The most important elements of protoplasm are carbon, hydrogen, oxygen, nitrogen, sulfur, and phosphorus. When it is viewed through the low-power objective of the microscope, protoplasm appears as a colorless or slightly gray semiliquid substance or material.

A typical green plant cell. If we prepare a thin section of a green leaf and examine it under a microscope, we can observe the typical parts of a plant cell as shown below.

DIAGRAM OF A TYPICAL PLANT CELL



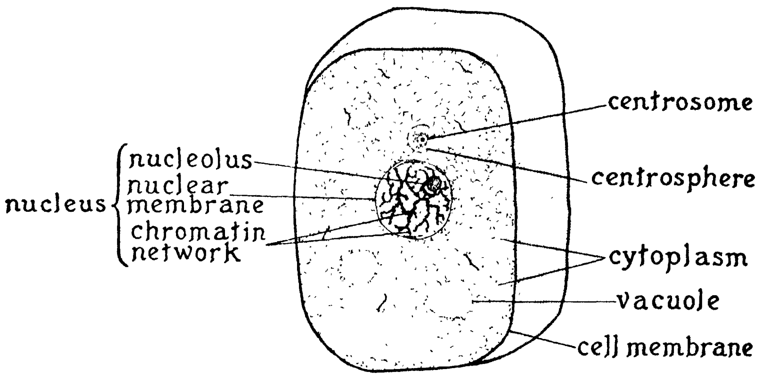
Cells may be thought of as building blocks, since they are structural units of all living things. It is from cells such as this that the bodies of plants are built.

PARTS OF A GREEN PLANT CELL

PART	DESCRIPTION	FUNCTION
Cell wall.	Nonliving complex material secreted by cytoplasm	Supports the soft protoplasm of the cell
Plasma (plăz'mȧ) membrane	Margin of protoplasm	Necessary for osmosis (ŏs-mō'sĭs)
Nucleus (nū'klē-ŭs)	Dense portion in protoplasm which has a nuclear membrane about it	Seems to control the cell activities
Nucleolus (nū-klē'ō-lŭs)	Dense spot within the nucleus	Function uncertain
Cytoplasm (sī'tō-plăz'm)	All protoplasm outside the nucleus	Performs all functions except reproduction
Chromatin-linin (krō'mȧ-tĭn-lī'nĭn)	Threadlike entanglement in the nucleus	Bearer of hereditary characters
Vacuoles (văk'ū-ōlz). . . .	Spaces within the cell	Containers of cell sap
Chloroplasts (klō'rō-plăsts) . .	Green bodies in the cytoplasm containing the substance chlorophyll (klō'rō-fĭl)	Assist in food making for the plant

A typical animal cell. If we study the following diagram of a typical animal cell, we shall see how it resembles and differs from a typical plant cell. Surrounding the plant cell

DIAGRAM OF A TYPICAL ANIMAL CELL



Carefully study this diagram, then compare it with the diagram of a typical plant cell shown on the opposite page. How do these two cells differ?

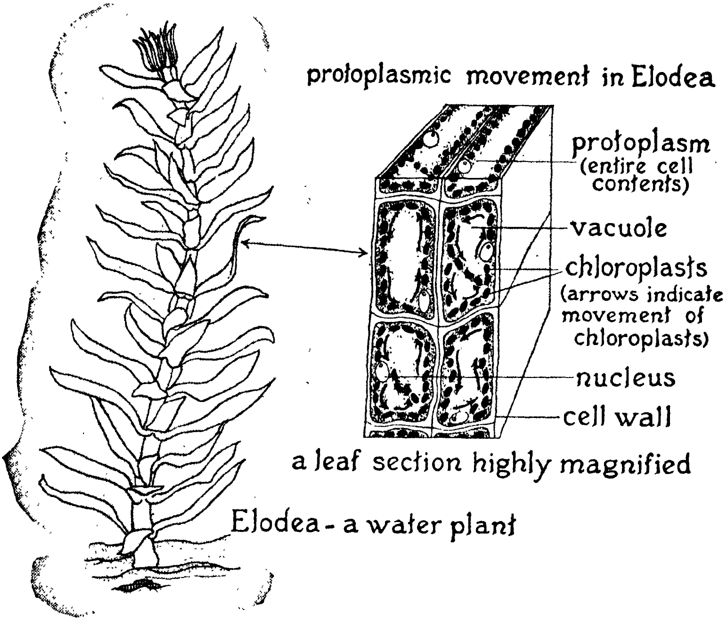
is a thick wall composed of a complex substance called *cellulose* (sĕl′ū-lōs). In the animal cell this thick wall is missing. Instead, there is only a cell membrane, as shown in the illustration above. In the plant cell we also noticed small bodies called *chloroplasts*. These, too, are missing in true animal cells, but are present in certain one-celled half-plant and half-animal organisms, such as Euglena (ū-glē′nȧ). The typical animal cell contains, near the nucleus, a *centrosphere* (sĕn′trō-sfēr′) inside which there is a smaller body called a *centrosome* (sĕn′trō-sōm′), which breaks up into two parts. The centrosomes are very important in the division of the animal cell. They also occur in the cells of certain lower orders of plants.

WHAT PROTOPLASM CAN DO

If we place a young living leaf of the water plant *Elodea* (ĕl-ō-dē′ȧ) on a slide and examine the cells with a compound microscope, we can actually see a stream of protoplasm moving

about in a cell, as shown in the drawing of an enlarged section below. A living organism can carry on only those functions which protoplasm itself can perform.

THE ELODEA AND ITS CELLS



The arrows within the cells indicate the movement of chloroplasts. Sunlight and moderate heat tend to stimulate the movement, resulting in greater protoplasmic action.

Protoplasm, as you can see, is very interesting. Its properties and functions may be described as follows:

1. *Irritability* (sensitiveness) is the tendency to react to certain stimuli, such as light, heat, and food. The microscopic one-celled animal amoeba (ȧ-mē′bȧ) responds to such stimuli as food particles by surrounding them. The cells of a green leaf respond to the stimulus of light by turning toward the light.

2. *Assimilation* (nutrition) is the process of changing absorbed food into new protoplasm.

3. *Respiration* is the process of taking in oxygen and giving off carbon dioxide.

4. *Excretion* is the process of throwing off the waste matter that results from oxidation.

5. *Growth* is the process of making more protoplasm than is needed for the production of heat and energy and for the repair of cells. It results from the process of assimilation.

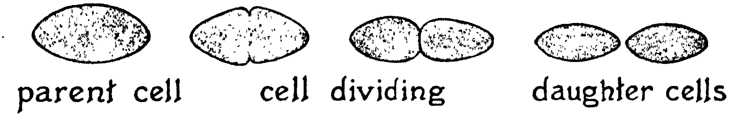
6. *Reproduction* is the process by which organisms produce other organisms of the same kind.

7. Other functions that certain cells perform are food getting, digestion, circulation, and locomotion.

How cells multiply. Living cells are either in a state of repeated division, and therefore bringing about growth, or, if not dividing, they are in a resting stage. There are two methods of cell division—*amitosis* (ăm′ĭ-tō′sĭs) and *mitosis* (mĭ-tō′sĭs).

The simpler type of cell division, *amitosis*, is accomplished by direct division. In this process the nucleus elongates and finally divides into two daughter nuclei (nū′klē-ī). (See the illustration below.) The cytoplasm also divides into two

HOW A SIMPLE CELL DIVIDES



Direct cell division takes place when one cell elongates and separates into two new cells. Such cell multiplications occur among simpler organisms, such as bacteria.

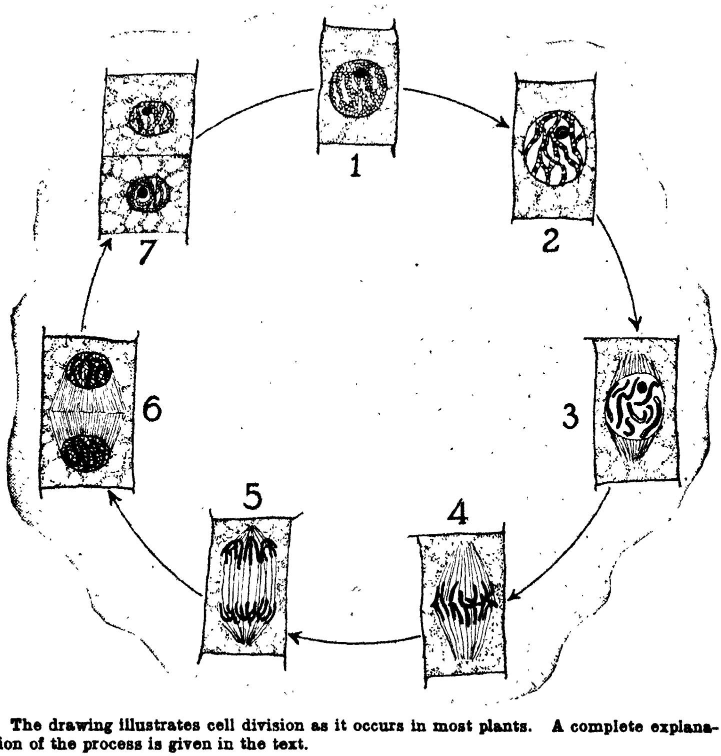
parts. Each part with its nucleus is now a new daughter cell similar to the parent. The daughter cell, of course, is smaller than the parent cell, but grows until it reaches full size and then divides. Amitosis occurs mostly in such simple forms of plant life as bacteria and certain algae and in Protozoa, single-celled animals.

Mitosis, or indirect cell division, is a much more complicated type of cell division than amitosis, but is the type most widely found. The illustration on page 78 shows the stages through which a typical plant cell passes in undergoing mitosis.

Multiplication in a typical plant cell. If we examine the sketches, we shall see that the process of mitosis is divided into a number of rather distinct steps or stages. In general, they are as follows:

1. *The resting stage.* The *nucleus* is inclosed in a nuclear membrane in which are imbedded a granular substance called *chromatin* and one or more *nucleoli.*

THE COMPLEX STAGES IN THE DIVISION OF A PLANT CELL



The drawing illustrates cell division as it occurs in most plants. A complete explanation of the process is given in the text.

2. *The spirem* (spī′rēm) *stage.* The chromatin granules arrange themselves upon a threadlike fiber of protoplasmic substance known as *linin.* This network of chromatin and linin is generally known as a *spirem.*

3. In the next stage the chromatin-linin thread or spirem splits crosswise into a definite number of pieces called *chromosomes.*

4. *The equatorial plate stage.* Outside the nuclear membrane, fibers develop from opposite sides of the nucleus. As the nuclear membrane and the nucleolus disappear, these fibers grow from the opposite sides or *poles* toward the center of the cell. Since the entire mass takes on the shape of a spindle, the separate fibers are called *spindle fibers.* A fiber from each pole becomes attached to each chromosome. All of the chromosomes arrange themselves midway between the two poles of the spindle.

5. *The diaster* (dī-ăs′tĕr) *stage.* The fibers attached to the chromosomes shorten. The chromosomes split lengthwise into equal parts, and the two halves are drawn toward the opposite poles.

6. *The dispirem* (dī-spī′rēm) *stage.* The daughter chromosomes at the two poles of the spindle unite to form a spirem, and a nuclear membrane surrounds each group. The spindle fibers thicken at their midpoint, or the equator of the cell, forming what is called a *cell plate.*

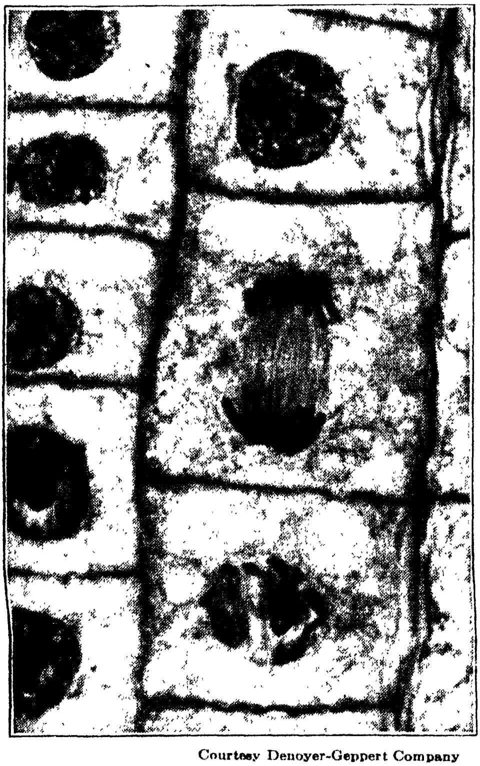
7. *Two new cells.* The spirem of each daughter nucleus breaks up, and a *nucleolus* appears in the nuclear sap. The daughter nuclei now resemble the mother nucleus except in size. The cell plate divides into two distinct parts, which become the new *plasma membrane* of the daughter cells. A cell wall is secreted between the plasma membranes. Cell division is now complete, and there are two new cells in place of one.

An explanation of mitosis in an animal cell is given in Unit Thirteen, page 629.

Plants and animals grow by cell division. The number of cells rather than the size of cells determines the size of plants and animals. Larger individuals, such as a large horse, have cells of the same size as those of a smaller individual, such as a small horse or colt. The difference in size is due entirely to a greater number of cells in the larger animal.

Cells working together — tissues. Cells play an important part in performing life functions. They determine exactly what a plant or animal can do. Even in the same plant or animal, cells differ greatly in shape, size, and function. Their variation in all these respects is commonly known as *cell differentiation*. If it were not for cell differentiation, all organisms would be composed of the same kind of cells. Then, of course, the organisms themselves would be alike.

A PHOTOMICROGRAPH OF CELL DIVISION IN AN ONION ROOT



Courtesy Denoyer-Geppert Company

What stage can be seen in the cell in the center?

As an animal grows, certain cells become very long and form *nerve cells*. Others become somewhat elongated and develop into *muscle cells*. Still others on the surface of the body, as in the skin, become flattened cells called *epithelial* (ĕp′ĭ-thē′lĭ-ăl) *cells*. Similar differences in shape and function of cells may be noted in the growth of a plant.

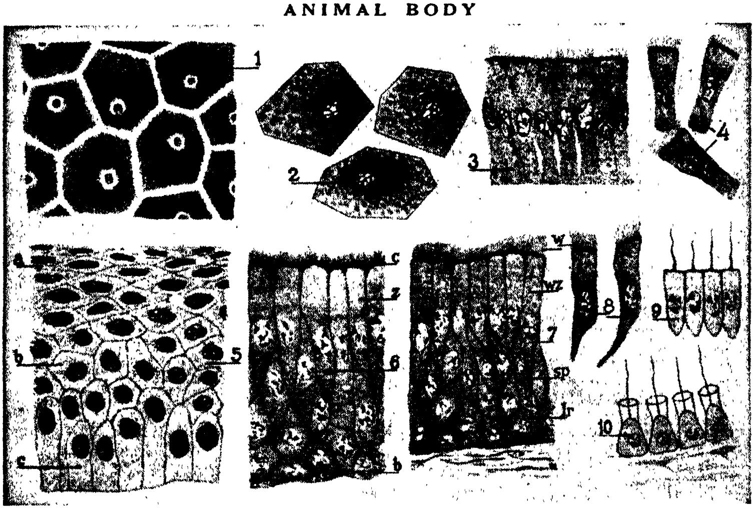
Tissues result from cell differentiation. A *tissue* may be defined as a group of cells which are alike in size, shape, and function. The skin of an onion is an example of plant tissue, whereas nerve tissue, muscle tissue, skin tissue, and many other tissues are found in animals. Between the cells of animal tissues is an invisible substance called *intercellular cement* which holds the

cells together. It is believed that this substance forms within the cell and passes out through the cell membrane.

Tissues that work together in carrying on a definite function are collectively known as an *organ.* Sometimes the tissues are very different, as in the case of the hand, which contains bone tissue, muscle tissue, nerve tissue, and skin tissue. A plant leaf is also an organ composed of several kinds of tissue.

Living and dead tissues. Plants and animals both contain some dead tissues. Plants, however, contain many more than

EPITHELIAL CELLS AND TISSUES OF THE ANIMAL BODY



Smalian Histologic-Embryologic Chart—Courtesy A. J. Nystrom & Company

1. Top view of epidermal (outer skin) cells of an animal showing nuclei
2. Individual epidermal cells
3. Side view of epidermal cells showing horny layer on top of them
4. Individual cells shown in 3
5. The skin is composed of several layers of cells arranged in layers showing flattened cells (a), five-sided cells (b), and columnar cells (c).
6. A cell covering consisting of columnar epidermal cells (z), with horny covering (c), and below it a connective tissue (b)
7. A portion of a mucous membrane. At its surface is a layer of columnar epithelial cells (wz) from the top of which hairlike structures known as cilia (w) extend. Below these cells are spindle-shaped cells (sp) and oblong cells (lr).
8. Individual cells from 7
9. A layer of flagellated epithelial cells as they are found in some of the lower animals (Protozoa). Instead of many cilia, a single flagellum (rapidly vibrating thread) develops as a process from each cell.
10. An epithelial layer made up of collar cells. Such cells form a layer about the interior of the pore canals of sponges.

do animals. In roots, stems, and leaves dead cells are useful as long as they do not decay. In some woody plants, especially trees, at least 90 per cent of the bulk is composed of dead wood, bark, and water tubes.

The nerve, gland, and muscle tissues of animals are all alive. When a cell from one of these tissues dies, it is dissolved and its remains are carried away. On the other hand, such structures as hoofs, nails, and scales are made up of dead tissues and are useful to the animal largely because they are rigid.

Problem 4. What hidden forms of life are revealed by the microscope?

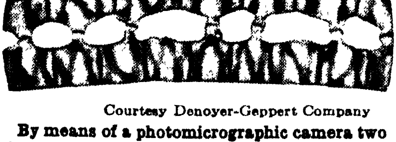
Under this problem we shall not study all the forms of life which are revealed by the microscope. Only a few simple organisms, both plant and animal, that can be easily secured for microscopic study will be considered.

MICROSCOPIC PLANTS

The plant with spiral bands — Spirogyra. The plant *Spirogyra* (spī′rō-jī′rȧ) is often referred to as "frog's spittle" or "pond scum." Although not attractive to a casual observer as it grows on the surface of ponds or sluggish streams, it is a very beautiful object for microscopic study. Specimens of Spirogyra are not difficult to obtain, since there are about seventy widely distributed species of the plant. The following description will be general enough to suffice for all species.

The Spirogyra is composed of tiny bright green threads or filaments that grow in masses and are slimy to the touch. When viewed with the low power of the microscope, each thread seems to be made up of many elongated cells arranged end to end. Cell walls can be clearly distinguished, and beautiful green bands called chloroplasts run spirally through the cell. Sometimes, in a microscopic

SPIROGYRA CONJUGATING



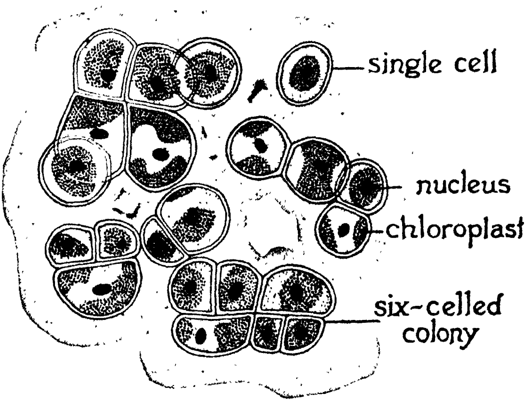
Courtesy Denoyer-Geppert Company

By means of a photomicrographic camera two filaments of Spirogyra were caught in the process of conjugating.

examination of Spirogyra, it is possible to see two of the filaments side by side in the process of *conjugation.* After this coming together the contents of one cell pass into the other cell and fuse with its contents. Thus a thick-walled resting cell is formed, which later, when favorable conditions occur, will develop into a new filament. This process is explained further in Unit Eleven, pages 581–583.

An alga which points the way—Protococcus. One of the simplest of all the algae is *Protococcus* (prō′tȯ-kŏk′ŭs). It has been chosen for study not so much for its beauty as for the fact that it is found almost everywhere and is easily procured at any season of the year. Protococcus grows in greatest abundance on the *north* side of trees, fences, and the like, where the rays of the sun never strike directly. For this reason it has been referred to as "an alga which points the way." This it literally does for people who need to get their directions when traveling in the woods. Doubtless we too shall find this little plant of service on some of our hikes.

A MICROSCOPIC ALGA—THE PROTOCOCCUS

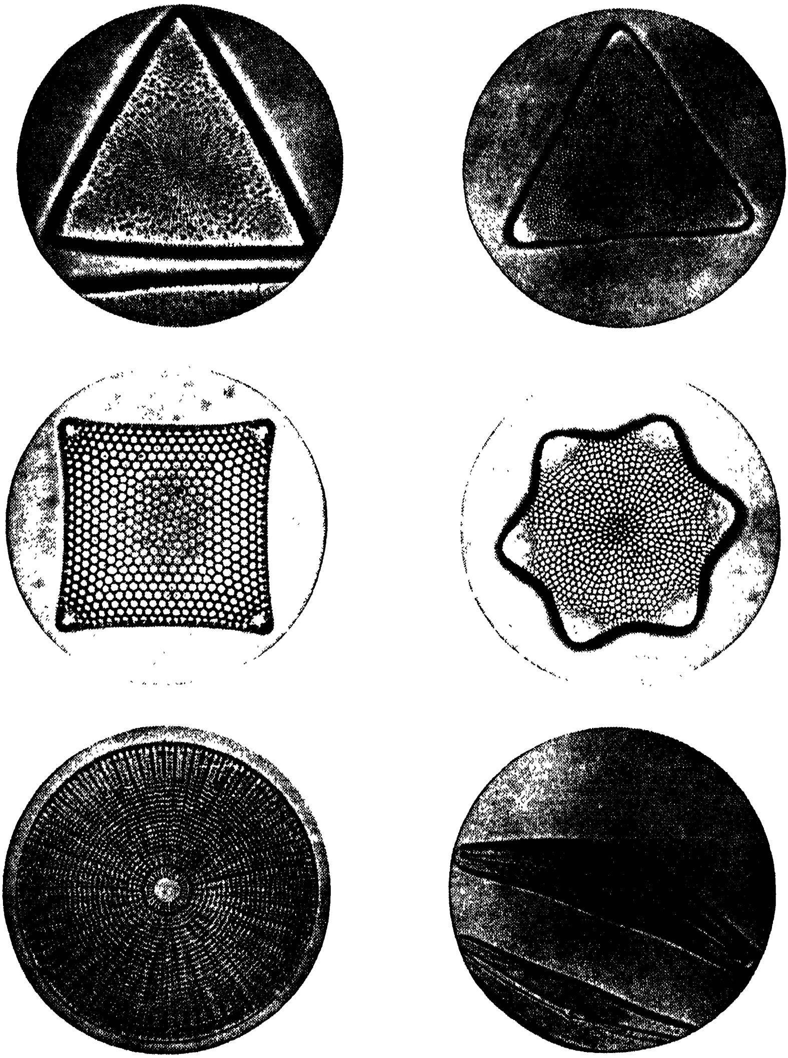


The green color on the north side of many trees is due to the presence of thousands of these microscopic one-celled plants.

The cells of Protococcus cling together in a mass and, when seen on the bark of trees or on damp wood, have the appearance of light green paint that has been thinly spread over the surface with a brush. The above illustration shows how the cells of Protococcus cling together.

Microscopic plants in armor—diatoms. Altogether there are several thousand species of diatoms, most of which are beautifully sculptured little organisms. They are found in

TINY PLANTS OF VARIED PATTERNS



Courtesy Max Poser, Bausch & Lomb Optical Company

These greatly magnified photomicrographs show six of the thousands of species of diatoms found in both fresh and salt water. Because of their color they are classed with the brown algae. Each diatom is housed in a glasslike cell wall.

abundance wherever there is a pond, lake, or stream. Because of their many shapes and forms we may expect them to be hard to identify. Moreover, they live both alone and in large groups or colonies. The colonies have the appearance of a reddish-brown gelatinous substance, and are usually found growing on submerged rocks, mud, or logs. Some diatoms float about singly in the water, whereas others unite into filaments and attach themselves to the stalks of plants. Diatoms have many beautiful individual forms, such as the crescent, the rod, the disk, the wedge, the oval, and the boat-shaped.

Probably the most interesting fact about diatoms is that they are all incased in boxlike suits of armor. The flintlike material of which the armor is composed is a substance called silica. This so-called armor is in two parts which fit together like a candy box and its lid. The casings are often found to be engraved with beautiful markings. One can imagine these markings as the work of tiny dwarflike creatures who with hammer and chisel seem ever to be cutting and grinding fine jewels for the crown of their queen.

The boat-shaped diatoms—Naviculae. Of the nonattached or free-swimming diatoms, the *Naviculae* (nȧ-vĭk′ŭ-lē) are an interesting group. In a fresh colony of these forms, great activity may be seen under the microscope. Should there be many individual diatoms, they will move from side to side and forward and backward. Suddenly they will pivot and cross one another's paths, narrowly missing other diatoms that seem to be in their way. It is intensely exciting to see two boatlike diatoms putting on full steam ahead for a certain spot where it seems evident they will collide. Usually they do not collide, but if they do, no harm seems to be done. After

THE BOAT-SHAPED DIATOM—NAVICULA

Courtesy Max Poser, Bausch & Lomb Optical Company

The characteristic shape of this diatom makes it easy to identify.

the collision they travel along side by side until, for some unknown reason, they are prompted to deviate from their mutual course. Their scientific name, Naviculae, means "boatlike," or literally, "little boats." The movements or maneuvers of Naviculae in water are as interesting as those of any ship.

In Units One and Seven are given descriptions of other forms of algae which are interesting specimens for microscopic study. Likewise, in Unit Three bacteria are treated in considerable detail.

MICROSCOPIC ANIMALS

The slipper-shaped animal—Paramecium. A tiny slipper-shaped animal, the *Paramecium* (păr'ȧ-mē'shĭ-ŭm), is common in ponds, ditches, and decaying vegetable infusions.[1] This organism is a giant among the one-celled animals called Protozoa (prō'tȯ-zō'ȧ), though scarcely visible to the naked eye. It is exciting to watch a group of these organisms doing such stunts as spinning round and round, darting forward and backward, and literally "looping the loop." Of course such exhibitions can be seen only under the microscope. We may prepare a Paramecium culture by placing some hay in a glass of distilled water. The mixture should be heated slightly in order to soften the hay, after which it should stand for about two weeks. The hay infusion will become discolored, and a scum will appear on the surface.

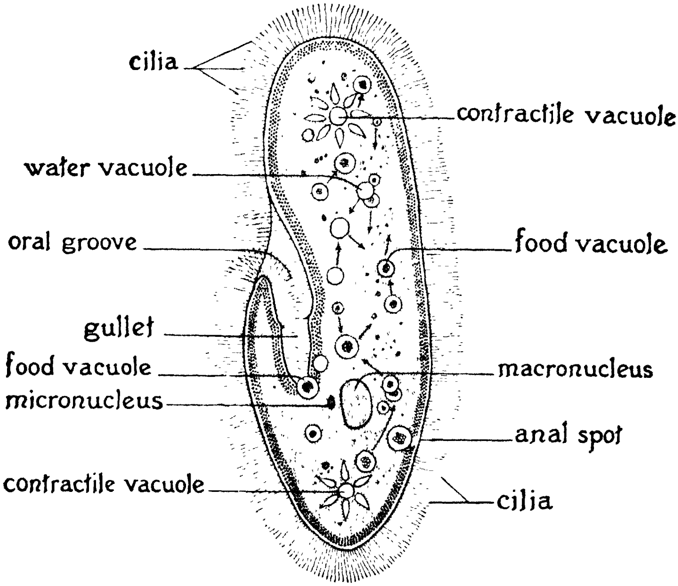
We may now prepare a specimen by placing a drop or two of the surface water on a slide according to the directions already given. When we examine the specimen under the low-power objective of a microscope, we shall see a regular circus of microscopic "busybodies" which seem to be ever moving, never tiring.

We may secure an individual Paramecium for study by placing on a slide a few cotton fibers and a drop of water from a hay infusion. The Paramecia become entangled in the fibers and are thus prevented from swimming out of view. If we study the labeled diagram of the Paramecium, we shall be able

[1] **Infusion—a fluid in which some substance has been soaked or steeped.**

to recognize the parts as they appear under the microscope. We shall also see, on the outside of the cell, tiny protoplasmic projections called *cilia* (sĭl′ĭ-ȧ). The locomotion of the Paramecium is caused by the movement of these cilia, which lash the water like hundreds of oars working in unison.

AN INTERESTING MICROSCOPIC ANIMAL
THE PARAMECIUM



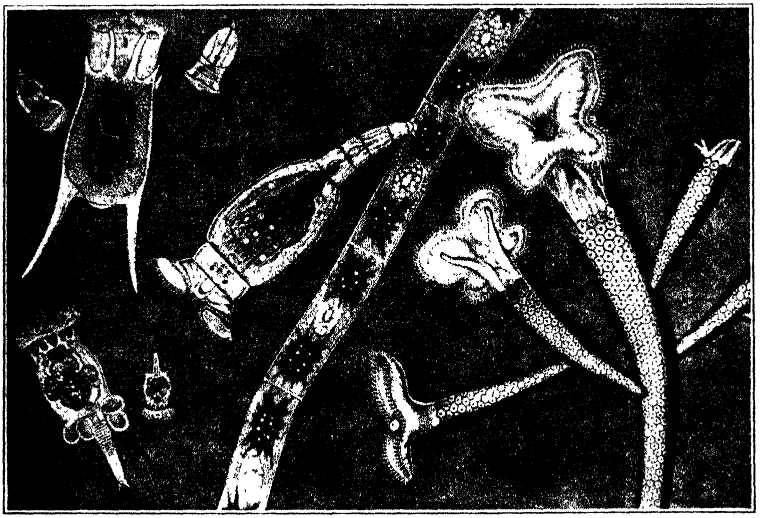
This tiny creature is capable of carrying on all the necessary life processes. Note the numerous cilia by means of which it swims about. (Diagrammatic)

One unusual activity of the Paramecium is its feeding process. At the end of its *gullet* is a *food vacuole,* into which food particles are brought by currents of water. When the food vacuole is filled, it moves to another part of the cell. A new vacuole is then formed to receive food particles. Thus food is dispersed throughout the organism. The solid waste products of this food are discharged through the *anal spot.* At each end of the Paramecium is a *contractile vacuole* which fills up with fluid and bursts at frequent intervals. In this manner the cell regularly rids itself of liquid waste materials.

The Paramecium has a large nucleus and a small nucleus, which are called respectively the *macronucleus* (măk'rô-nū'klê-ŭs) and the *micronucleus* (mī'krô-nū'klê-ŭs).

Other interesting microscopic animals. The Paramecium has been chosen for detailed study because of its availability. There are many other microscopic forms of animal life that might be studied. The cyclops (sī'klŏps), for instance, is a one-eyed fresh-water crustacean, which may be seen impudently flicking its tail, winking its one eye, or darting off to hunt Paramecia. The stentor, too, has interesting habits.

ANIMALS WITH WHEEL-LIKE MOTIONS—THE ROTIFERS



Tauber Microscopic Chart—Courtesy A. J. Nystrom & Company

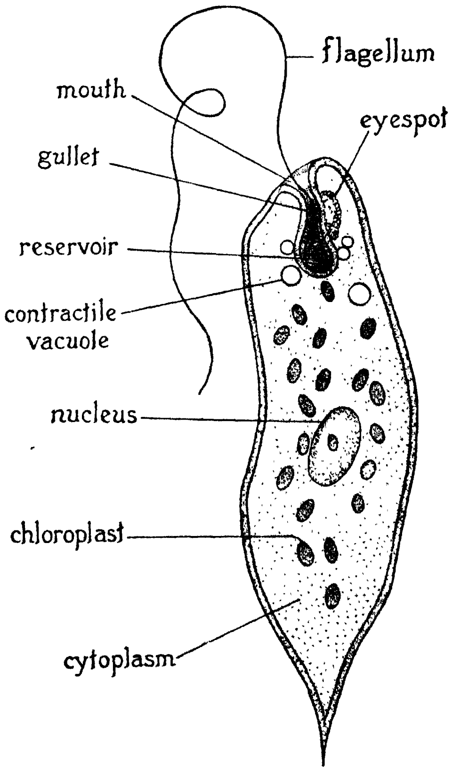
These microscopic animals are about one-sixth of an inch in length. The lashing of the cilia at the unattached end gives them a wheel-like motion. They are found chiefly in fresh water and are fascinating forms for microscopic study.

When this little animal is attached to some object, it is shaped like a trumpet, but when it is swimming, it is shaped like a pear. Some colonies of rotifers (rō'tĭ-fērz) have the appearance of a revolving sphere as they travel along, since the individuals are always swimming out from the center. In Unit Seven will be found descriptions and pictures of several other tiny animals that may be studied now if time permits.

THE SO-CALLED HALF-PLANT HALF-ANIMAL MICROSCOPIC ORGANISMS

Perhaps it has never come to our notice that certain microscopic organisms resemble both plants and animals. This, however, is true, and we shall now study two forms of life that are claimed by both botanists and zoölogists. As we study these forms, it will be interesting to note the strange mixture of characteristics that exists.

THE HALF-PLANT HALF-ANIMAL CREATURE—THE EUGLENA



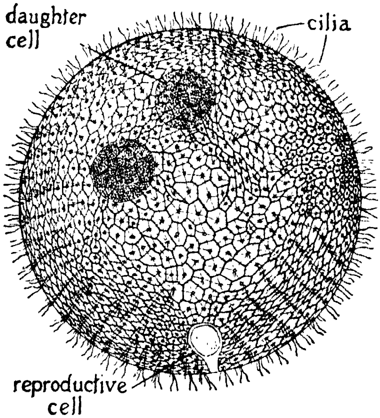
The status of this creature is in dispute, for both botanists and zoölogists claim it. (Diagrammatic)

A borderline organism —Euglena. The *Euglena* is a simple elongated cell, which although somewhat elastic maintains a more or less constant shape. A long, slender, whiplike *flagellum* (flȧ-jĕl′ŭm) extends out from an opening in the cell, which is called the *mouth*. A *gullet* leads from the mouth to the stomach or *reservoir*. Into this reservoir several *contractile vacuoles* pour their contents, which are waste products. Near the reservoir is a little spot of red coloring matter. This is called an *eyespot* because it is thought to be sensitive to light. The *nucleus* is near the center of the cell. Scattered throughout the protoplasm are little oval-shaped *chloroplasts* in which food is manufactured with the aid of chlorophyll.

In this regard the organism is much like a plant, since animals do not contain chlorophyll. On the other hand, its structure and habits are without a doubt animal, and not vegetable. In view of these facts, the Euglena must be considered as a borderline organism, part plant and part animal.

The rolling colony—Volvox. Another striking form of borderline life is *Volvox* (vŏl′vŏks), which consists of colonies made up of a single layer of hundreds of individual green cells grouped into a hollow ball. Arising from each cell are two small *cilia,* which move the green ball along in the water with a rolling motion. Each colony is about the size of a pinhead.

A MICROSCOPIC CREATURE THAT IS COLONY-MINDED
THE VOLVOX



Collections of these fresh-water organisms form spherical colonies. Labor is divided and the outer cells rotate by means of cilia. Some of the inside cells carry on reproduction. (Diagrammatic)

Some authorities call Volvox a multicellular individual rather than a colony because of the close association and frequent division of labor among its cells.

When the colony becomes mature, some of the individuals, as shown in the illustration, enlarge, lose their cilia, and become *reproductive cells.* These enlarged cells divide many times and finally form a new group of cells called a *daughter colony.*

The Volvox sometimes employs a more complex method of reproduction. Certain cells expand and enter into the hollow ball, where they swim about as *egg cells.* Certain other cells enlarge and divide into small slender, free-swimming cells which also enter the hollow ball and swim about. These cells are known as *sperm cells.* The sperm cells fertilize the egg cells and thus produce new colonies.

SUGGESTED ACTIVITIES

I. Self-Organization Summary

A. History and Development of the Microscope
1. How did people in early days explain the cause of disease?
2. Mention some of the early microscopists and state the contribution of each.
3. How did Leeuwenhoek's microscope differ from those in use today?

B. The Microscope and Its Operation
1. Name the parts of the compound microscope and tell how each part is to be used.
2. List the steps in preparing a slide.
3. Give the directions for focusing a microscope.

C. Cells and Cell Structures
1. Name the parts of a typical plant cell. State the function of each part.
2. How does a typical plant cell differ from a typical animal cell?
3. Explain the steps in cell division.
4. Define tissue and organ and give examples of each.

D. Some Microscopic Plants and Animals
1. Describe diatoms, Spirogyra, and Protococcus.
2. Give interesting facts concerning some of the microscopic animals discussed in this unit.
3. Why do the botanists and zoölogists both claim Volvox in their respective fields?

II. Laboratory Study

A. How to Secure Specimens
1. The larger water plants usually have many microscopic organisms attached to their surfaces. Such submerged plants as Elodea and Vallisneria (eelgrass) and such floating vegetation as lily pads are frequently teeming with attached microörganisms. If these are placed in jars of pond water and permitted to stand for several days, the microscopic forms of life will multiply profusely. This procedure will insure a supply of diatoms, desmids, Euglena, and certain protozoans.

2. Filaments of algae, such as Spirogyra, certain protozoans, and such microscopic forms as cyclops, hydra, and rotifers may be secured from stagnant water.
3. Paramecia and other protozoans, as well as some bacteria, develop abundantly in hay infusion.

B. Examining Microscopic Organisms
1. Reread that part of Problem 2 which deals with the preparation and observation of microscopic slides. You will probably want to observe specimens of Paramecia, Euglena, diatoms, Spirogyra, and Protococcus. See whether you can find the parts of these organisms described in this unit. If you draw several of these organisms, you will find it easy to remember their fascinating forms.
2. Observe stained slides of onion skin for the purpose of noting tissue structure and the stages of mitosis.

III. Special Reports

A. Consider the following topics and work out special reports on as many of them as time permits:
1. Photomicrography
2. Economic importance of diatoms
3. Economic importance of Protozoa
4. Chalk formation — sedimentary rock formation
5. Progress in differentiation of structure and function in microscopic life
6. Brief reviews of books on the foregoing subjects

REFERENCES[1]

1. De Kruif, Paul. *Microbe Hunters.*
   a. First of the microbe hunters, p. 3
2. Drew, A. H., and Wright, Lewis. *The Microscope.*
   a. Practical optics of the microscope, pp. 21–45
   b. Microscopic manipulation, pp. 108–127
   c. Pond and marine life, pp. 150–200
3. Park, William H., and Williams, Anna W. *Who's Who among the Microbes.*
   a. Early discoveries, pp. 3–16
   b. Animal microbes or Protozoa, pp. 239–251

[1]The pages listed here are those found in the editions indicated in the alphabetical list of references given at the end of this book.

4. Yates, Raymond F. *Exploring with the Microscope.*
   a. The monsters of microland, pp. 43–62
   b. The teeming jungle of microland, pp. 85–113
   c. Seashore sideshows, pp. 135–140
5. *Book of Popular Science, The.*
   a. Seeing the hitherto invisible, Vol. 8, pp. 2515–2528
   b. Biography of Leeuwenhoek, Vol. 13, pp. 4564–4566
6. *Compton's Pictured Encyclopedia.*
   a. Exploring the mysteries of the infinitely small, Vol. 9, pp. 156–158
   b. How cells divide, Vol. 2, pp. 112–114
7. *New Wonder World, The.*
   a. Growth by cell multiplication, Vol. 10, pp. 11–12
   b. A story of cells and protoplasm, Vol. 10, pp. 99–100
8. *World Book Encyclopedia, The.*
   a. The cell and its parts, p. 1268
   b. Protoplasm and its properties, pp. 5852–5853

VISUAL AIDS

FILMS (16 mm.)

A. Bray Pictures Corporation, 729 Seventh Avenue, New York City.
   1. Protoplasm—the Beginning of Life. 1 reel, silent, $35.00.
      Illustrates such characteristics of protoplasm as movement, irritability, assimilation, and reproduction
B. Indiana University, Extension Division, Bloomington, Indiana.
   1. Living Cell. 1 reel, silent, $1.00 per day.
      Pictures the growth of single-celled organisms, as yeast, amoeba, and Paramecium; of many-celled forms, as hydra and flatworm; and of tissue cells
C. Gaumont British Picture Corporation, 1600 Broadway, New York City.
   1. Amoeba. 1 reel, sound. Apply for price.
      Shows the production of pseudopods and also an amoeba pursuing and capturing its prey
D. Walter O. Gutlohn, Inc., 35 W. 45th Street, New York City.
   1. Marvels of the Microscope. 1 reel, sound. Apply for rate.

CHARTS

A. **Series Smalian Histologic. Title: Protozoa. No. 1.**
B. **Series J–K–Q Botany. Title: Freshwater Algae. No. 30.**

UNIT THREE

CONQUERING DANGEROUS MICROBES

SUGGESTIONS TO THE TEACHER

Louis Pasteur once said, "It is within the power of man to eradicate from the face of the earth all germ diseases." This statement, together with the great demonstration he gave of what could be done, has so stimulated the world that man is slowly but surely making his statement true. It is hard to believe that so much could be accomplished within the brief span of fifty or sixty years.

The work of eradicating disease germs does not fall upon scientists alone. It requires the help of everybody. In fact, the victims of disease may bear a greater responsibility in eradicating disease than do the scientists themselves. Scientists may point the way to what should be done, but if people do not heed the suggestions little can be accomplished. People everywhere, therefore, should be thoroughly aroused to their responsibility in the matter.

The purpose of this unit is to help the student study dangerous microbes and modern methods of fighting disease. He should be greatly interested in the subject because he has already learned something of the effect of dangerous microbes in his health education. Therefore he is ready to approach the subject for a more intensive study.

OBJECTIVES

I. Facts and principles

A. To learn the characteristics of specific microörganisms that endanger man's existence

B. To learn the specific controls which man has developed to check the attacks of his enemies

II. Attitudes

A. To appreciate the number and ceaseless activity of microscopic enemies and to follow specific practices for their control

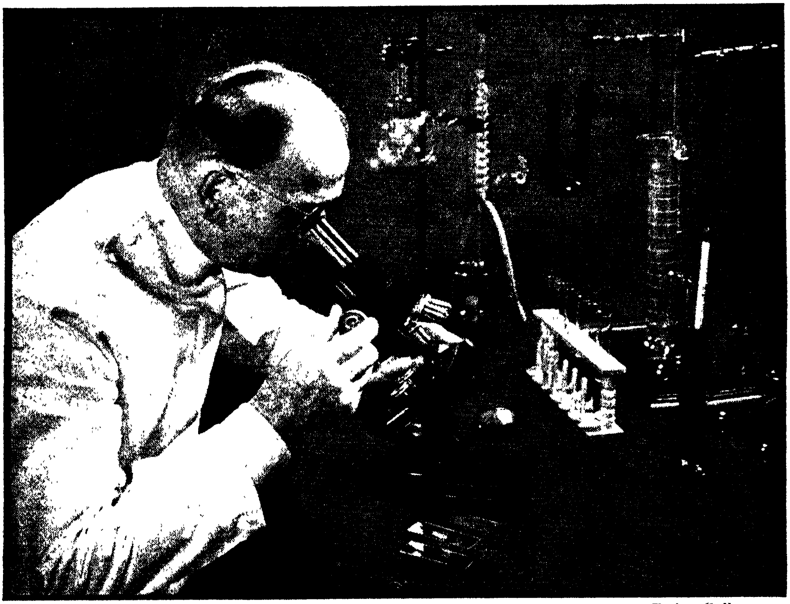
B. To develop respect and admiration for the accomplishments of leaders in the field of scientific medicine

C. To encourage scientific research directed toward the discovery of further means of checking the ravages of microscopic organisms

UNIT THREE

CONQUERING DANGEROUS MICROBES

THE MAN BEHIND THE SCENES



Ewing Galloway

Back of every important discovery in the field of bacteriology and health is a man who has spent many long hours, perhaps years, in scientific research. The man in this picture is examining various specimens through a microscope.

MICROBE DETECTIVES

PREVIEW

Armed with the microscope the microbe detective is greater than any Sherlock Holmes of fiction. With this wonderful piece of scientific apparatus, he has been able to ferret out the haunts of the most dangerous enemies of man and to bring the fight against them into the open. These enemies include

bacteria, yeasts, molds, and Protozoa. Everywhere about you, on land or sea or in the air, these invisible foes are mobilized, ready to attack. Thanks, however, to the master microbe detectives who have followed Leeuwenhoek, men now possess the necessary information to wage an intelligent battle that may ultimately wipe out dangerous microbes or at least render them harmless. Microbe detectives have delved into the hiding places of microbes, learned their habits and their methods of attack, and in most cases found out how best to repulse them. The romantic story of microbiology (mī'krô-bī-ŏl'ô-jĭ) is a tale of supreme human achievement. It is impossible in a single unit to give credit to or even to list all the men of science and medicine who have aided in the conquest of dangerous microbes. Such a story would fill the pages of many books.

The following problem questions will serve to guide you in a condensed study of the subject of diseases caused by microbes. You must bear in mind, however, that this unit does not give a complete picture of diseases, because many are not caused by microbes.

PROBLEMS

1. **What are the life habits and characteristics of pathogenic[1] organisms?**
2. **What should we know about certain diseases caused by pathogenic organisms?**
3. **How are diseases that are caused by pathogenic organisms resisted by the body?**
4. **How are diseases that are caused by pathogenic organisms combated by society?**
5. **What laboratory techniques[2] are used in the study of bacteria?**
6. **Who are some of the dramatic figures in the development of techniques for the control of disease?**

[1] Pathogenic (păth-ô-jĕn'ĭk) — disease-producing.
[2] Techniques (tĕk-nēks') — methods or ways of doing.

Problem 1. What are the life habits and characteristics of pathogenic organisms?

The term *microbe* includes both plant and animal microorganisms, that is, organisms that may be seen only under the microscope. In the plant kingdom microbes are known as *bacteria* and belong to the lowest form of life. In the animal kingdom they are known as *Protozoa* and also belong to the lowest form of life. Both bacteria and Protozoa are single-celled organisms some forms of which are pathogenic, or disease-producing. The classification of microörganisms is difficult, because no distinctive characteristic separates the lowest plants from the lowest animals.

Since the terms "microbes," "bacteria," "germs," and "bugs" are used rather indiscriminately to designate disease-producing organisms, we should study these terms for their correct meanings. The following definitions point out the differences in meaning:

Microbes: any microörganisms
Germs: any pathogenic organisms
Bacteria: one-celled plants that lack chlorophyll
Protozoa: one-celled animals
"Bugs": a term often applied as a misnomer to disease-producing organisms

OUR MICROSCOPIC ENEMIES

Pathogenic Bacteria

The microscope has revealed that the tiny organisms of the invisible world harmful to man are the pathogenic bacteria which belong to the plant kingdom and the pathogenic Protozoa which belong to the animal kingdom.

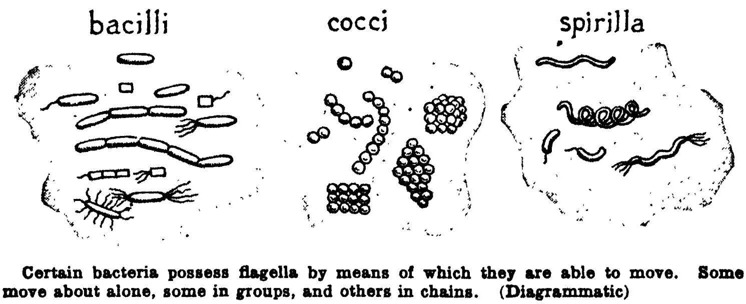
Where bacteria live. Bacteria have a wider range than any other living things, for they are found in all parts of the world. Given sufficient moisture, one form or another will find conditions suitable for growth almost anywhere. The range of temperature under which bacteria may live varies from below

0° Centigrade to as high as 100° Centigrade, but most forms thrive best at 25° Centigrade (80° Fahrenheit). Then, too, bacteria have many habitats. Some live only in human tissues, others only in lower animals, and a few thrive in both human tissues and those of lower animals. Other bacteria grow only in plant tissues. The greatest number, however, live in dead organic matter. Some cannot live without oxygen, but to others it is poisonous and causes them to die.

Let us repeat: *bacteria are almost everywhere.* Because they are so exceedingly small, they escape notice even though millions of them may be present.

Bacteria—the smallest living plants. Because bacteria are so small, it is scarcely possible to measure them in terms of fractions of an inch. A *micron* (mī'krŏn), therefore, is used as the unit of measurement. This name comes from a Greek word meaning "small." A micron is only a thousandth part of a millimeter, or 1/25,000 of an inch, in length. Since the average bacterium is about 1/25,000 of an inch, or one micron, long, it would take a million bacteria placed end to end to extend the length of a yardstick. It has been estimated that it would take three hundred billion bacteria to weigh a pound.

THREE GENERAL SHAPES OF BACTERIA



Certain bacteria possess flagella by means of which they are able to move. Some move about alone, some in groups, and others in chains. (Diagrammatic)

Shapes of bacteria. Bacteria may be classified into three groups according to their shapes, as follows:

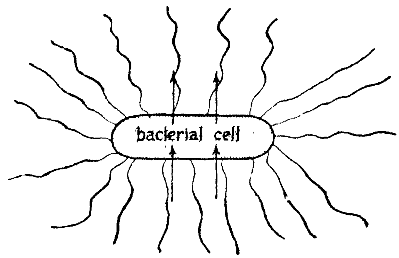
1. *Bacillus* (bȧ-sĭl'lŭs), plural *bacilli* (bȧ-sĭl'ī)—rods, or elongated sacs

2. *Coccus* (kŏk′ŭs), plural *cocci* (kŏk′sī)—spheres, or little balls
3. *Spirillum* (spī-rĭl′ŭm), plural *spirilla* (spī-rĭl′lȧ)—spirals, like corkscrews without handles

The *basic* forms are the rod, the sphere, and the spiral, although under certain conditions the form of any one species may vary somewhat, as in larger plants or animals.

How bacteria live—food supply and nutrition. Since bacteria do not contain any green coloring matter (chlorophyll), they are unable to manufacture their own food and must get it from their environment. This food must contain the chemical elements nitrogen, carbon, hydrogen, oxygen, phosphorus, and sulfur. Bacteria are able to live, however, under surprisingly strange conditions, and some of them are found wherever there is a trace of organic substance[1] and a little moisture. In their food requirements and in the type of surroundings, bacteria vary widely. For example, (1) some grow best on the simplest foods, whereas others require more complex foods; (2) some live best at low temperatures, growing on snow and ice; (3) some prefer high temperatures, being able to thrive even in hot springs; (4) some grow well in the presence of oxygen and are therefore called *aërobic* (ā′ĕr-ō′bĭk) *bacteria*; (5) some grow only where there is no oxygen and are called *anaërobic bacteria;* (6) and some limit their habitats to the bodies of living plants and animals. The bacteria that inhabit living organisms and obtain their food from them are called *parasites*. Not all of such bacteria are harmful. As a matter of fact, many, called *nonpathogenic*, are useful. Nitrogen-fixing bacteria, for instance, live in the

HOW A BACTERIUM "EATS"



Food is digested (made soluble) by means of a digestive juice, called an enzyme, given off by the cell. The soluble food is then absorbed through the cell wall. In this diagram the arrows below indicate the food entering the cell. The arrows above indicate the giving off of the enzyme. (Diagrammatic)

[1]Organic substance—a substance derived from living organisms.

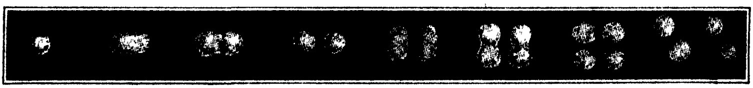
roots of legumes and return nitrogen to the soil in such form that it can be used by plants.

The bacteria that attack nonliving organic matter are called *saprophytes* (săp′rō-fītz). For the most part, these are friends of man. Of the utmost importance, for example, are the saprophytic (săp-rō-fĭt′ĭk) bacteria that (1) sour milk, (2) ripen cheese, (3) change alcoholic liquids, such as cider, to vinegar, and (4) rot dead plants and animals so that their elements return to the soil, thereby enriching it for future plant growth. We can readily see that these bacteria render a great service to man. They help to make the environment a suitable place in which to live.

It will be interesting to note that bacteria digest their food on the outside of their bodies. Both parasitic and saprophytic bacteria give off a substance called an *enzyme* (ĕn′zīm) that serves as a digestive juice[1] and spreads over the outside of the cell bodies. When the food is digested, it is absorbed and is either oxidized for the purpose of releasing energy or is used to form new protoplasm. It is this process of assimilation that causes bacteria to grow and to reproduce in such numbers that groups or colonies are formed.

Simple but rapid reproduction. Under favorable conditions bacteria grow rapidly to a certain size—there being a maximum for each species—and then divide into two approximately

STAGES ILLUSTRATING THE DIVISION OF BACTERIA



Courtesy *Book of Knowledge* by permission of the Grolier Society

The parent cell first elongates, then division takes place and two daughter cells are produced. Under favorable conditions this process takes from twenty to thirty minutes.

equal parts by simple direct cell division, often called *fission.* The average time for the completion of this process under favorable conditions is from twenty to thirty minutes. The table on the following page illustrates the surprisingly large numbers of bacteria that may be produced within a few hours.

[1]Digestive juice—a substance secreted by organisms which converts foods into a soluble form that can be assimilated.

12:00 noon	1 bacterium	1:40 P.M.	32 bacteria
12:20 P.M.	2 bacteria	2:00 P.M.	64 bacteria
12:40 P.M.	4 bacteria	2:20 P.M.	128 bacteria
1:00 P.M.	8 bacteria	2:40 P.M.	256 bacteria
1:20 P.M.	16 bacteria	3:00 P.M.	512 bacteria
		(and so on)	

If a single bacterium should split into two bacteria at 12:20 P.M. and this process were to be continued (that is, an equal splitting of each new cell every twenty minutes), how many bacteria would there be at 12:00 noon the following day? The number is almost unbelievable. If bacteria multiplied only once an hour, there would be 17,000,000 descendants. In twenty-four hours each of these would produce 17,000,000 more, and so on and on and on! Think of it! Before long they would fill the oceans and overrun the earth and become the sole inhabitants of this entire planet. Fortunately, however, nature has provided a means of preventing such a catastrophe.

In the first place, when bacteria become too numerous, they die of their own wastes. In the second place, when conditions are unfavorable, many bacteria go into a dormant or *spore* stage. This stage is so named because spores form within the cell wall. As this happens, the protoplasm shrinks because of the water that is given off, and a firm membrane or spore wall develops about it. Bacteria remain in this spore stage until conditions again become favorable for their growth.

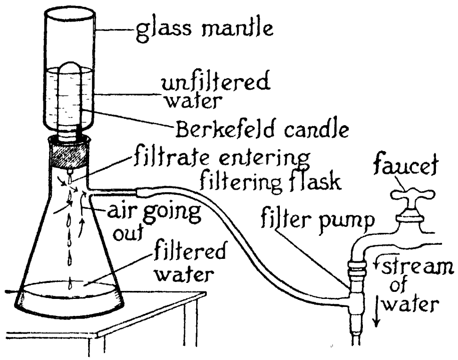
Pathogenic Protozoa

Protozoa in the animal world correspond to bacteria in the plant world, as has already been pointed out. They include all of the one-celled animal forms. All these organisms are microscopic in size, but are usually larger and much more complex in structure than bacteria. Illustrations in Units Two and Seven show that Protozoa vary so in shape and size that no general description will fit all types. Many Protozoa are particularly dangerous and cause a number of diseases, such as malaria, African sleeping sickness, and amoebic dysentery.

Only disease-producing Protozoa are treated here. Other forms of Protozoa are described in Unit Seven.

Beyond the range of the microscope—the invisible filterable viruses. Some forms of life are so small that they cannot be seen even under the most powerful magnification of a microscope. Such organisms are called *filterable viruses.* They get their name from the fact that they pass through the clay or unglazed porcelain filters that are used to catch bacteria and Protozoa. Only by the effects they produce do we know these microörganisms exist. Scientists have determined that they cause such diseases as rabies, infantile paralysis, measles, and smallpox. Thus what they lack in size these deadly enemies of man and other animals make up in strength.

FILTERABLE VIRUSES



Filterable viruses are organisms so small as to pass through the finest filters. In the device shown above, the unfiltered water, containing bacteria, is made to enter the flask by the creation of a vacuum through the action of a filter pump. All the microörganisms except the filterable viruses are retained in the Berkefeld candle which is shown on top of the flask.

One of the greatest proofs that filterable viruses exist comes from the process of inoculation. Scientists have found that they can take a filterable virus from a sick animal, inoculate another animal with it, and produce symptoms of the same disease. Furthermore, the filterable virus from this inoculated animal may be used to inoculate any number of others. Even after many successive transfers from one animal to another, the virus loses none of its power.

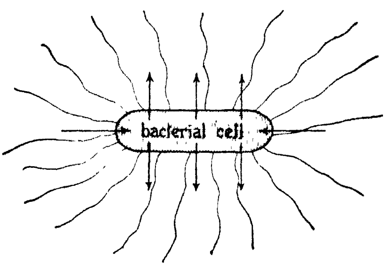
Problem 2. What should we know about certain diseases caused by pathogenic organisms?

How bacteria cause disease. Before bacteria can harm a person, they must gain an entrance to the body. Numerous, however, are the ports of entry. They may enter through a break in the skin, such as even the slightest scratch or the

bite of an insect; through the air passages when one is breathing; through the food tube when one is eating or drinking; through the eyes when they are rubbed by infected objects; and in many other ways. After the bacteria have gained entrance, they may produce disease if present in sufficient numbers and if *immunity* (the power to resist disease) has not been established. They do this through their waste products, which act as *toxins*, or poisons, in the body.

How diseases are spread. There are many different ways to group the diseases set aside for consideration in this unit. Perhaps the best method is to group them according to the manner in which they are transmitted, thereby emphasizing how to be on the alert to avoid them. Of course such a classification will not be entirely accurate, since many diseases are transmitted in more than one way. The following table, however, indicates the means by which certain diseases are most commonly spread.

HOW BACTERIA CAUSE DISEASE



This is a diagrammatic sketch of a bacterium, greatly magnified. Bacteria commonly cause disease through excretions or toxins. The arrows pointing inward at the ends indicate food taken in. The arrows pointing upward and downward indicate toxins given off.

METHODS OF SPREADING DISEASES

DISCHARGES OF NOSE AND MOUTH	INTESTINAL DISCHARGE	INSECT BITES	CONTACT
Pneumonia	Typhoid fever	Malaria	Trachoma
Influenza	Asiatic cholera	Yellow fever	Leprosy
Diphtheria	Dysentery	Trench fever	Anthrax
Scarlet fever		Bubonic plague	Hydrophobia
Common colds		Typhus fever	Tetanus (lockjaw)
Mumps		African sleeping sickness	Venereal diseases
Infantile paralysis			
Tuberculosis			
Whooping cough			
Measles			
Smallpox			
Septic sore throat			

FACTS ABOUT SOME OF THE MORE IMPORTANT MICROBE DISEASES

The tabulation on the preceding page lists only a few of the diseases caused by germs. Among the diseases mentioned are some of the most common as well as the most dangerous. It would not be practical or possible in this type of book to consider all the diseases caused by germs, or to prescribe even for those which are discussed. The content will be limited, therefore, to the history, characteristics, and spread of a few typical diseases. We should, of course, know the symptoms and characteristics of the most common diseases, their manner of spreading, and how best to avoid them. Then, too, we should make an honest effort to utilize such information in order to safeguard ourselves, our relatives, and our friends. This does not mean, of course, that we should attempt to treat our own ailments. On the contrary, we should call a doctor at the first symptoms of illness.

HOW COLDS ARE SPREAD

Protect others from colds. Always sneeze and cough into a handkerchief. If bacteria were really as large as those shown in this illustration, people would certainly try to avoid them.

Colds and Their Allies

"Only a cold." The common cold is the most frequent of all acute *infectious* diseases (diseases produced by pathogenic organisms). It is important to know that colds are *infectious*—that is, may be transferred from one person to another—and that they are caused by germs. No one germ, however, is responsible for producing them. On the contrary, they are caused by any one of many kinds of bacteria, or by several different kinds in combination. Colds by themselves are not fatal, but they pave the way, by lowering body resistance, for

the entry and growth of more dangerous microbes, such as those causing influenza, pneumonia, and tuberculosis.

It is estimated that the average person has from three to five colds a year. The prevalence of colds will be more forcibly brought to our attention if we keep a check on the members of our biology class. How many students are afflicted from day to day, and how many have to stay away from school because of colds?

Types of colds. Colds may be classified under two headings: chest colds, those in which the bronchi (brŏng′kī) and lungs are involved; and head colds, in which the mucous membrane of the mouth, nose, pharynx (făr′ĭnks), and sinuses (sī′nŭs-ĕs) is affected. Both types need careful treatment.

How to fight against colds. With colds, as with all other diseases, prevention is the greatest factor. Unfortunately, too many people suffering with colds do not stay at home and properly care for themselves. They go forth sneezing, coughing, and in other ways spreading the disease to others. We should not be afraid of offending such people by taking precautions to protect ourselves.

The best defense against colds is the building up and maintenance of body resistance. Cold germs do not ordinarily thrive in healthy tissue. Most people know the formula for keeping physically fit. That colds are permitted to cause so much suffering, not to mention loss of time and money, is partly the result of negligence and indifference.

THE GREAT WHITE PLAGUE

A world-wide disease—tuberculosis. One out of every eight deaths in the world is caused by tuberculosis. In the United States conditions are somewhat better, but even here one out of every eleven deaths is caused by this dreaded disease. What a ghastly picture would be painted if we were to describe all the sufferings, deaths, hardships, and economic losses laid at the door of the tubercle (tū′bẽr-k′l) bacillus!

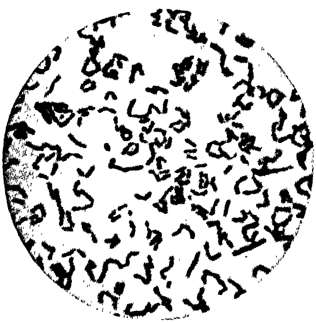
The tuberculosis germ is everywhere. No one of us escapes it. The findings of a famous Italian pathologist are submitted

as typical of its prevalence. He examined the bodies of seven hundred individuals and found in all except three of them evidences of active or healed tuberculosis.

Characteristics of tuberculosis germs. Only within the last century have we known the exact cause of tuberculosis. The question was solved in 1882 when Robert Koch (kōk), a German physician, discovered the tubercle bacillus, *Mycobacterium tuberculosis*. This discovery is considered one of the most important in the field of health. Just how Dr. Koch carried on his experiment will be told later.

The tubercle bacilli are rod-shaped organisms about six microns in length. They may attack any part of the body, but are most likely to attack the lungs. Here they irritate portions of the lung tissue, causing infection. The protective agencies of the body come to the rescue and gradually build up *tubercles*, or circular walls of defense, around the infected parts. The size of the tubercles varies from the size of a pinhead or pea to very large areas, depending upon whether or not the body agencies are successful in resisting the bacilli in the early stages of attack. The disease is said to be arrested in a particular region when the body is successful in building a wall about the germ-infected area.

THE DEADLY GERM OF TUBERCULOSIS



Courtesy *New Wonder World*

This photomicrograph shows the tubercle bacillus magnified about 1,000 diameters. The germ is a tiny thing indeed, but it causes untold misery.

It is important to know that, whereas tubercle bacilli are able to withstand extreme conditions of heat and cold, the direct rays of the sun kill them readily. Sunlight, then, is one of man's foremost allies in the fight against tuberculosis. It is also important to know that the disease itself is not hereditary. This statement is equally true of all germ diseases. Scientists have found that not the diseases themselves, but only a susceptibility to them, may sometimes be inherited.

How to prevent tuberculosis. The problem of prevention is one that should receive very serious consideration in our study of tuberculosis. Indeed, here is a case in which "an ounce of prevention is worth a pound of cure." The following general principles should guide us in our fight against the disease:

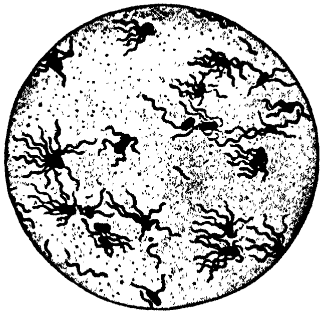
What to Do	*What Not to Do*
1. Be out in the fresh air as much as possible.	1. Breathe foul air continually or for long periods of time.
2. Bathe the body in sunshine.	2. Live in dim, dark places.
3. Get ample sleep and rest.	3. Keep late hours.
4. Choose easily digested foods, including plenty of milk.	4. Become excessively fatigued.
5. Exercise moderately in the open.	5. Lead a sedentary life.
6. Keep the teeth in good condition.	6. Choose foods carelessly and eat rapidly.

A Filth-borne Disease

Typhoid fever. The progress that has been made in cutting down the toll of typhoid fever is one of the greatest feats of modern sanitation. The death rate from this dreaded disease has been cut from 36 per 100,000 in 1900 to about 4 per 100,000 at the present time. Some cities have a death rate of even less than 1 per 100,000. All this has been accomplished through the health agencies that watch our water and milk supply, that regulate the disposal of sewage, and that safeguard us from other sources of contamination.

Characteristics of the typhoid germ. The typhoid bacillus, *Bacillus typhosus* (tī-fō′sŭs), discovered in 1880, has been found

THE GERM THAT CAUSES TYPHOID FEVER



Courtesy W. M. Welch Manufacturing Co.

A photomicrograph of Bacillus typhosus. Note the flagella which are characteristic of this bacterium.

to be a short, rather thick rod, with rounded ends. It is very active and moves about by means of flagella. Like most parasitic bacteria, the typhoid bacillus grows best at body temperature (98.6°), but will also grow at temperatures as low as 59° and as high as 106° Fahrenheit. Given sufficient moisture, it will remain alive for months or even years.

How typhoid bacilli are spread. Typhoid germs invade the body by way of the mouth. They spread largely through materials contaminated by the excreta of typhoid patients. Therefore, when cases of typhoid fever appear, the water supply and the food supply are usually suspected. Water from rivers, lakes, and wells may be contaminated with sewage containing typhoid bacilli. Typhoid germs have even been found in raw oysters that have been gathered from bodies of water into which sewage containing typhoid bacilli has been emptied.

EVIDENCE AGAINST THE HOUSEFLY

Courtesy United States Department of Agriculture

This picture shows colonies of bacteria that developed after a fly had walked across the culture medium of an ordinary Petri dish.

The common housefly is one of the most dangerous agents in our immediate environment. Since it breeds in filth and lives in filth, it naturally spreads such diseases as typhoid fever. We can readily understand how this happens when we think of how the fly moves about. From garbage or excreta it may pick up typhoid bacilli and carry them on its feet to our homes and even to our food. If we study the picture of the housefly's leg on page 109, we shall notice how well it deserves the title "typhoid fly," which has often been applied to it.

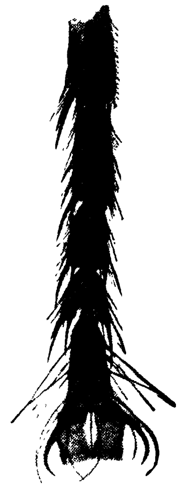
The story of "Typhoid Mary." Human beings may also be carriers of typhoid fever germs. In 10 per cent of the cases typhoid bacilli are excreted from the body for thirty days after

recovery from the disease; in 4 per cent of the cases for forty-five days after recovery; and in 2 per cent of the cases during the remainder of life. The individuals making up this 2 per cent become chronic carriers of the disease.

The story of "Typhoid Mary" illustrates how dangerous typhoid carriers really are. This woman served as a cook in several homes over a period of years. A short time after her arrival in each of these homes, some member of the household became ill with typhoid fever. Finally she was suspected of being the cause and was removed to a detention hospital, where she was examined. A peculiar condition was found. At certain times typhoid bacilli in enormous numbers were present in the intestinal excreta, while at other times there were none at all. Thus the typhoid germs seemed to multiply and die intermittently within her body.

"Typhoid Mary" was kept at the hospital for a period of three years, after which she was released with the understanding that she would not again accept a position as cook. She soon forgot her agreement, however, and a few years later was employed as a cook in a hospital. Some time after her arrival an epidemic of typhoid fever broke out. When the food was analyzed, it was found to be infected with typhoid bacilli. This led to an investigation, and the cook was identified. Wherever she went, "Typhoid Mary" was a menace to society carrying germs of destruction and death.

FLY'S GERM CATCHER



Courtesy Max Poser, Bausch & Lomb Optical Company

This photomicrograph shows the sticky foot pads and hairlike projections to which bacteria adhere. When the fly alights upon food, thousands of bacteria are deposited.

How to prevent typhoid fever. It is important to remember the following facts regarding the prevention of typhoid:

1. The germ is found only in human excrement and in things contaminated by human feces (fē′sēs), urine, bath water, and related substances.

2. It enters the body only through the mouth.
3. Unless conditions in the home are very satisfactory, a typhoid patient should be sent to a hospital. This insures the safety of the family and the community.
4. Everything that leaves the sickroom must be thoroughly disinfected by the use of either heat or chemicals.
5. Physical examinations should be required of all persons engaged in the preparation of foods. This is the only way to eliminate the menace of the typhoid carrier.
6. The milk and water supply of most cities is adequately protected, but somewhat greater protection is needed in rural communities.
7. The breeding places of the typhoid fly, such as manure heaps, garbage, and other filth, should be destroyed as far as possible.
8. The Widal (vē′däl) test, which is explained on page 122, will show whether the body contains typhoid germs and whether a person is taking the disease. Typhoid vaccination may be used as a protection against the disease. This was clearly demonstrated by the United States government during the World War.

THE SO-CALLED "BAD-AIR" DISEASE

Malaria. In ancient times it was believed that malaria was caused by bad air or poisonous gases which came from the soil. In fact, the name *malaria* comes from the two Italian words *mala* (mä′lä), "bad," and *aria* (ä′rê-ä), "air." It was thought that night air is more dangerous than day air. Some attributed the spread of malaria to the use of swamp water for drinking purposes. The ordinary name for malaria was "chills and fever" disease.

Malaria has played an important part in the history of nations. The fall of Greece and particularly that of Rome were due in some measure to the ravages of fever which came with the importation of slaves from Africa. A great malarial belt extends around the earth at the equator, reaching north and south to about the fortieth parallel. For this reason the

valuable resources of tropical Africa and South America have remained practically undeveloped to this day. Malaria is the most common of all tropical diseases.

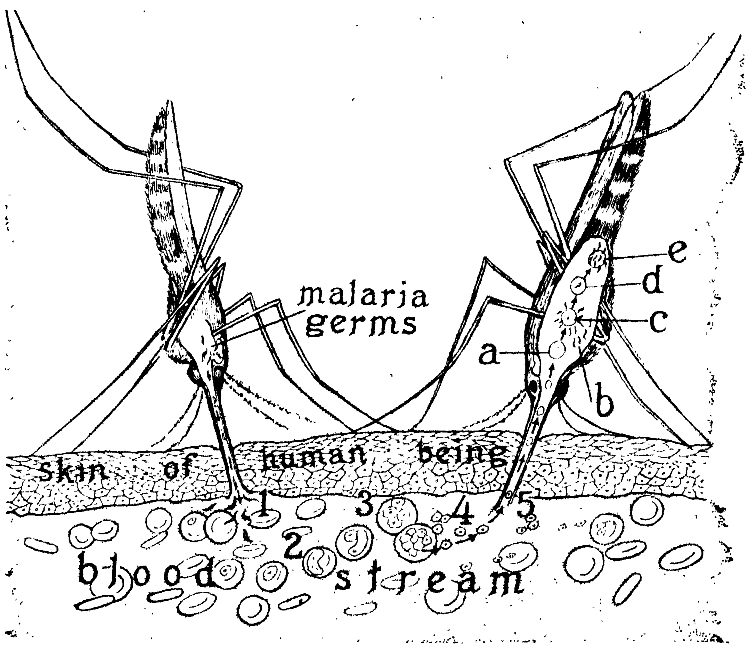
How the mystery of malaria was solved. Until recent years it was difficult to combat malaria because people did not know what caused the disease or how it was spread. Today, however, we can fight the disease because all mystery has been eliminated. We know it is caused by a microscopic protozoan parasite, *Plasmodium malariae* (plăz-mō′dĭ-ŭm mȧ-lā′rĭ-ē), and that it is always spread by the female Anopheles (ȧ-nŏf′ē-lēz) mosquito.

The germ *Plasmodium malariae* was discovered in 1880 by Charles Laveran (lȧv′räN′), a French army medical officer stationed at Algiers. He found that in the red blood corpuscles of all persons suffering from the disease there were small amoeba-like organisms. These tiny microbes were not present in the red blood corpuscles of healthy people. When the blood of a malaria patient was injected into a well person, Laveran found that the disease soon developed. He did not discover exactly how the disease was spread, but suggested that a blood-sucking insect might be the cause.

The real cause of the spread of malaria remained a mystery until 1897. During that year Major Ronald Ross found definitely that it was scattered by the female Anopheles mosquito, and he thereby verified the hypothesis of Laveran. He had spent several years in India, where malaria was responsible for the death of more than one million people annually. By experimentation he found that if susceptible persons kept their homes carefully screened from mosquitoes, they would not contract the disease. Furthermore, infected mosquitoes were sent from Italy to England, where they were allowed to bite several volunteers, two of whom contracted the disease even though they had not been near malaria patients. These were the final tests which convinced physicians that the female Anopheles scatters the germs of malaria fever. Since this discovery great progress has been made in preventing the spread of malaria in many parts of the world.

The malaria germ has two hosts. Since the germ *Plasmodium malariae* lives within living organisms and obtains its food from them, it is a *parasite.* It requires two hosts[1]—man and the female Anopheles—to complete its life cycle. When the female Anopheles pierces the skin of a human being who has malaria, it sucks up some of the malaria germs. These germs undergo certain changes within the body of the mosquito and then pass to its salivary glands. If the mosquito then bites

THE LIFE CYCLE OF THE MALARIA PARASITE



1. At the left malarial cells enter the human blood stream as a result of the bite of a female Anopheles mosquito.

2. The cells enter the red corpuscles, where they feed, grow, and multiply, forming numerous spores.

3. The new spores pass from the red corpuscles into the blood stream.

4. The spores are now taken up by another mosquito when it pierces the skin, as shown at the right. Note the following parts giving rise to another batch of spores: (a) egg or female cell; (b) sperm or male cell; (c) sperm cells clustered about egg cell; (d) fertilized egg cell; (e) fertilized egg cell giving rise to new spores.

[1]Host—a plant or animal from which an organism obtains its food.

a human being, some of the cells pass into his blood and enter the red blood corpuscles. Here they feed, grow, and multiply, forming from six to sixteen spores. Finally the corpuscles burst and the new malarial cells enter the blood stream, where they are carried to the various organs of the body. The patient suffers fever when the malarial cells burst the red corpuscles. He suffers chills when the malarial cells again attack the blood corpuscles. These conditions explain the old name "chills and fever" disease.

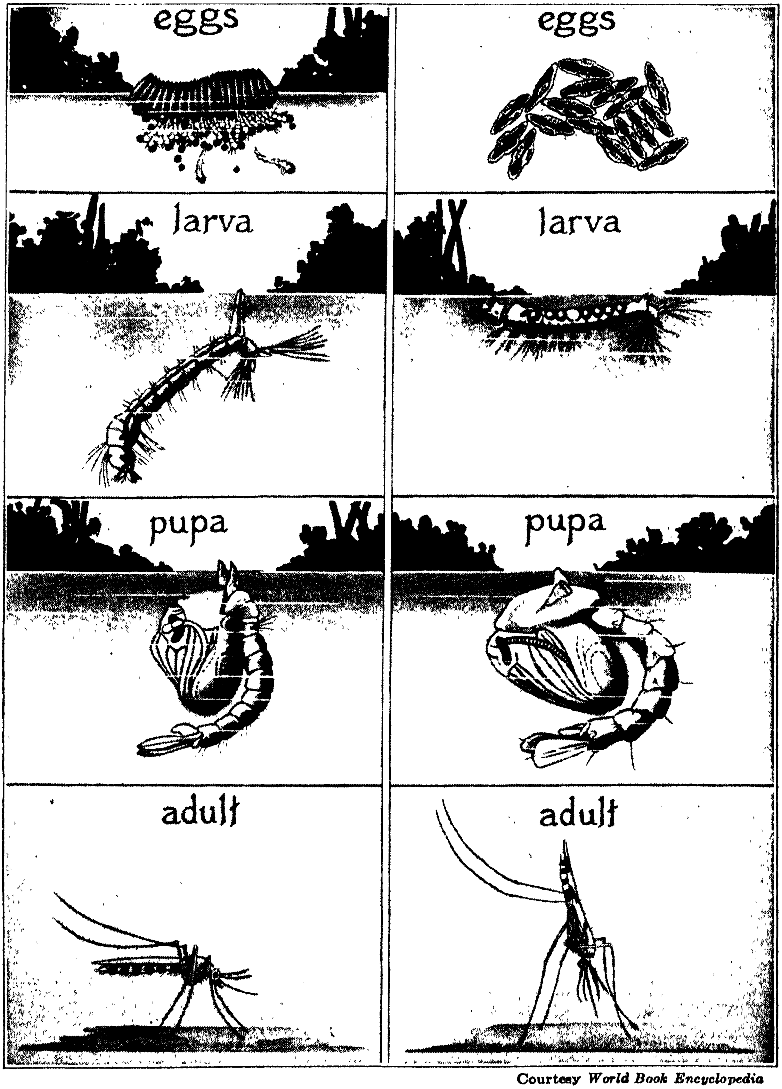
How to prevent malaria. Since Laveran and Ross have solved the age-old mystery as to the cause of malaria, and proved that the female Anopheles mosquito is the agent that spreads the disease, the solution for its prevention clearly lies in the destruction of Anopheles mosquitoes. To carry on a successful warfare against mosquito enemies, we must know their life habits.

The common mosquito with which we are familiar is the harmless *Culex* (kū'lĕks). Although it annoys us and makes us uncomfortable at times, it does not transmit malaria germs and therefore is not dangerous. By referring to the sketches on the following page, we can readily distinguish between the harmful Anopheles and the harmless Culex. The Anopheles holds its abdomen at an angle to the surface on which it alights, while the Culex holds its abdomen parallel to the surface. In the case of the larva forms, the positions are reversed.

There are four stages in the life cycle of the mosquito: the *egg*, *larva*, *pupa* (pū'pȧ), and *adult*. The eggs of mosquitoes are laid in water, where they hatch into larvae (lär'vē) commonly called wrigglers, which swim about in the water. The larvae develop into pupae (pū'pē), which live in the water in a dormant state. The adults emerge from the pupae and then leave the water as full-grown mosquitoes. They will breed in any stagnant water.

The illustration on the following page shows the four distinct stages in the life history of the harmless Culex mosquito and the harmful Anopheles mosquito.

LIFE HISTORY OF TWO MOSQUITOES



Courtesy *World Book Encyclopedia*

Culex (on the left) is a harmless mosquito, though extremely annoying at times. It is the Anopheles mosquito (on the right) that spreads malaria. Note that Culex, at rest, is semi-vertical as a larva and horizontal as an adult, while the reverse is true of Anopheles.

How to conquer the mosquito. The following measures may be used to destroy the Anopheles or to offset its assaults upon man:

1. Draining swamps and other stagnant bodies of water
2. Spraying crude oil or Paris green on the surface of stagnant water in order to suffocate the larvae
3. Stocking ponds with fish, since larvae constitute one of their foods

Contact Diseases

It is impossible within limited space to give full details concerning diseases transmitted by contact. Among the more virulent of these diseases are the following:

Anthrax (ăn′thrăks) is a disease primarily of domestic animals, though it sometimes attacks human beings. This disease affects the entire body, and is usually fatal in less than a day, though recovery sometimes occurs.

Leprosy (lĕp′rȯ-sĭ) is a disease of the skin, nerves, and mucous membranes. Those suffering from it are isolated, usually in communities far from other human habitations.

Trachoma (trȧ-kō′mȧ) is a chronic destructive inflammation of the conjunctiva of the eye, which may cause blindness. It is associated with filth.

Among other diseases transmitted by contact are syphilis and other venereal diseases, hydrophobia, and tetanus (lockjaw).

Problem 3. How are diseases that are caused by pathogenic organisms resisted by the body?

Successful resistance to the development of disease in our bodies is called *immunity.* Those agencies that resist disease from without we call "outer body protectors"; those that resist it from within, "inner body protectors."

OUR BODY PROTECTORS

Outer body protectors. Fortunately, our bodies are provided with a number of parts which serve as guards against the entrance of disease germs. The table on the following page lists these protectors and explains their functions.

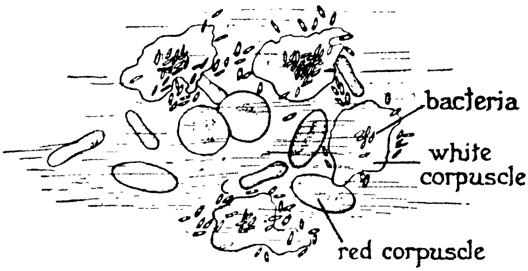
Protectors	Methods of Protection
Unbroken skin	The thickness of the surface layer of cells bars the entrance of bacteria to the body. Infection occurs but rarely in unbroken skin, and then only through the ducts of sweat glands or hair follicles.
Mucous membranes of mouth, nose, eyes, and intestinal tract	Mucus is a slippery secretion which tends to destroy certain bacteria. Its constant flow also keeps microörganisms moving so rapidly that they cannot do much damage.
Eyelids, eyelashes, and tears	Eyelids and eyelashes prevent the entrance of many bacteria. Tears wash away foreign substances and tend to destroy microörganisms.
Hairs of the nasal passages	These hairs point outward and strain dust particles and bacteria from the air we breathe.
Cilia of the bronchial tubes	The hairlike cilia are in constant motion and with their quick strokes continuously force foreign substances toward the mouth so that they may be expelled.
Various reflexes, as sneezing and coughing	These reflexes remove irritating agents from the throat before serious harm is done.
Secretions of the mouth, stomach, and intestines	The saliva in the mouth, gastric juice in the stomach, and bile from the liver possess germ-killing properties.

Inner body protectors—phagocytes and antibodies. If the germs of disease get by the outer body protectors and into the blood or lymph (lĭmf) stream, they meet another very important bulwark that nature has set up to resist their attack. When we successfully combat such a disease as diphtheria, for instance, it is because of one or both of the following protective agencies: (1) certain white corpuscles called *phagocytes* (făg′ō-sīts) which destroy invading germs; or (2) *antibodies* which accumulate in the blood and kill bacteria or neutralize their toxins (bacterial poisons). Generally, antibodies work with the white corpuscles in destroying germs.

The policemen of the body—phagocytes. There are several kinds of white corpuscles in the blood, each of which has a different function. The white corpuscles that are particularly useful in the battle against dangerous microbes may well be called "policemen of the body." They are similar to the

amoeba in that they are very active and are constantly changing their form. The phagocytes do not confine their microbe hunting and killing activities to the blood stream alone, but work their way out of the blood vessels into other parts of the body, particularly the lymph spaces between tissue cells.

THE "POLICEMEN" OF THE BODY—THE PHAGOCYTES



Certain white corpuscles called phagocytes present in the human blood stream tend to engulf and destroy invading bacteria and thus to ward off disease.

When microbes invade the body, the "policemen" increase in number and collect in groups where their combined services are needed. In this way they engulf and devour the invaders. For example, in boils there is an accumulation of phagocytes about the infected parts. A fighting army surrounds the invading germs and in due time consumes them. Many of the white corpuscles are rendered useless in the fight and, with the consumed germs, are cast off as pus. It is thought that germs that get into the lymph stream are filtered out and destroyed by the lymph glands. This explains the swollen lymph glands under the jaw during tonsillitis and on the underside of the arm following certain infections.

Allies of the phagocytes—the antibodies. The second type of body protection against disease is even more peculiar than the first. It comes from substances called *antibodies,* which are produced by the body cells and are contained in the liquid part of the blood. Antibodies cannot be definitely described, since they have never been seen with the microscope nor located by chemical tests. That they exist, however, is known by the definite results which they produce.

The following chart includes the different types of antibodies and states the particular function of each.

ANTIBODIES AND WHAT THEY DO

NAME	FUNCTION
Lysins (lī′sĭnz)	Dissolve bacteria.
Agglutinins (ă-gloo′tĭ-nĭnz)	Cause germs and red corpuscles to stick together in clumps. This makes it easier for the phagocytes to catch and engulf the germs.
Opsonins (ŏp′sô-nĭnz)	Prepare the bacteria so that they will be more readily digested or devoured by the phagocytes.
Precipitins (prê-sĭp′ĭ-tĭnz)	Remove bacteria and various protein substances from solution so that they are harmless.
Antitoxins (ăn′tĭ-tŏk′sĭnz)	Do not affect the bacteria directly, but neutralize the toxins produced by them. Antitoxins may either occur normally in the blood or they may be gradually developed as a result of the presence in the body of bacterial poisons. The bacteria causing a disease may be concentrated in a certain area, but the toxins formed by the bacteria rapidly spread to all parts of the body. Consequently it is essential not only that the bacteria be killed but also that the poisonous toxins be neutralized. Hence antitoxins are extremely important.

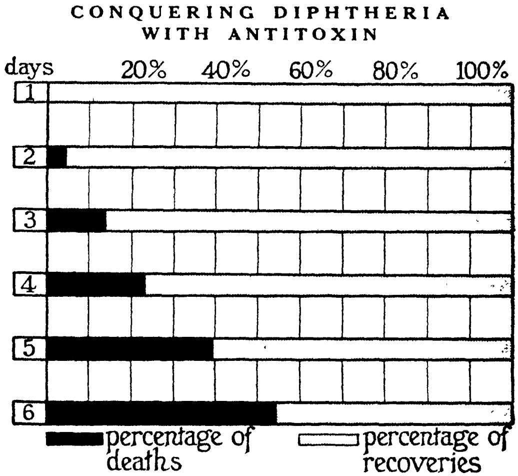
THE TYPES OF IMMUNITY

There are two important types of immunity to disease: *natural immunity* and *acquired immunity.*

Natural immunity. If a person inherits a more or less permanent resistance to a disease, he is said to possess a *natural immunity* to the disease. For instance, some people are practically immune to tuberculosis or colds. This means that their bodies possess certain protective substances, such as antibodies, that fight and destroy the germs of the disease, thus preventing the disease itself.

Acquired immunity. *Acquired immunity* may be either *active* or *passive* in form. The active form is a result of the

formation of protective substances (antibodies) which are produced to resist the germs or the toxins of a disease. In this case, the body cells actually fight the disease. The passive form is the result of injecting *antitoxin* or immunized *serums* (sē′rŭmz) into a person's body to keep him from taking a certain disease.



That chances of recovery are increased by the early use of antitoxin is clearly shown by the above statistics.

How active acquired immunity is produced. Frequently immunity to a disease is acquired by suffering an attack of the disease itself. While a person is ill with some such disease as smallpox, diphtheria, or typhoid fever, enough antibodies are produced in his body not only to bring about recovery but also to protect him against further attacks of the disease for many years, and often throughout life.

Active acquired immunity may also be brought about by vaccination, or inoculation with a *vaccine* (văk′sĭn). A vaccine consists of a virus or of a solution that contains either dead or weakened disease-producing bacteria. The purpose of inoculation is to bring about immunity to a disease by stimulating the body cells to produce antibodies. The bacteria in the vaccine are weakened just enough so that they will produce antibodies but not the disease itself. Thus by inoculation a person can build up resistance to a disease without actually having the disease.

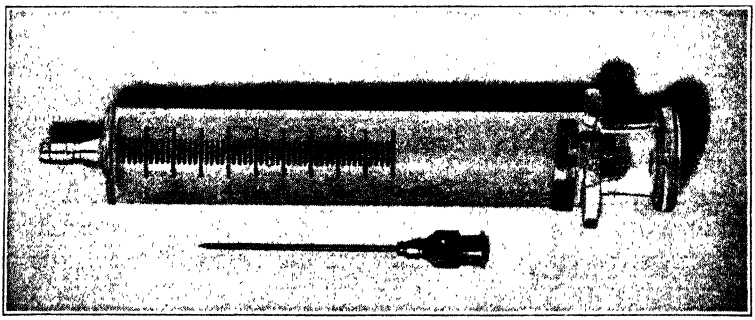
In the case of smallpox a weakened living virus is used for inoculation. Since scientists have been unable to find a

bacterium that causes smallpox, they believe the disease comes from a filterable virus. It was early discovered that cows were often affected by a disease known as cowpox, which seemed to be a mild form of smallpox. Hence physicians tried using the virus from a cow having cowpox for inoculating persons they wished to keep from getting smallpox. The experiment worked, and as a result hundreds of thousands of lives have been saved. The virus for vaccine today is obtained by inoculating a calf with a weakened solution of smallpox virus and then collecting cowpox virus from the calf after it has developed the disease. To make the vaccine the virus is dried and mixed with glycerin.

In the case of typhoid fever, dead typhoid bacilli suspended in a salt solution are used to prevent people from taking the disease.

Active immunity may also be secured by the injection into the blood stream of toxins or bacterial waste—poisons from which the bacteria have been removed by a filtering process. These toxins stimulate the body cells to produce antibodies.

AN INJECTING SYRINGE



Courtesy Chicago Apparatus Company

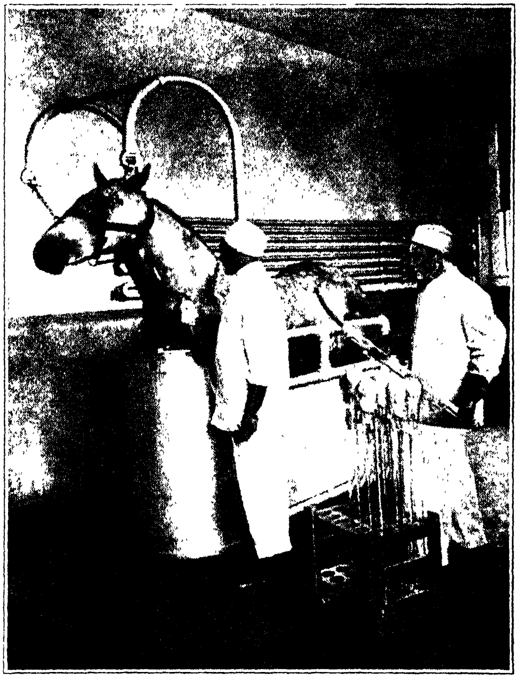
This instrument is used for inoculating and for administering vaccines.

In inoculation against scarlet fever small quantities of toxin are used. In immunization against diphtheria, some antitoxin is added to the toxin, to dilute it and make it safer for use.

Active immunity obtained by any of the foregoing processes is slow to develop but is usually lasting in its effects.

How passive acquired immunity is produced. Passive immunity differs from the active type in that the antibodies in the antitoxins or immunizing serums used in vaccination have been produced in another person or animal. Another difference is that the immunity is immediate in its effects but does not continue for so long a time. The injection of antitoxins or immunizing serums does not stimulate the body cells to produce antibodies. Antitoxin containing antibodies is used both in the treatment of those who have a contagious disease and as a preventive for those who have been exposed.

HOW ANTITOXIN IS SECURED FROM HORSES



Courtesy Parke, Davis & Company

When healthy horses are inoculated with diphtheria toxin, large quantities of antitoxin are produced in their bodies. The picture shows the process of collecting blood from the jugular vein of a horse. The serum containing the antitoxin must be separated from the blood.

TESTS FOR DISEASE

Tests have been developed for certain diseases. These tests may be used to determine the presence of (1) suspected bacteria, (2) antibodies that result from the presence of diseases. The chart on the following page shows some of the tests and states their uses. Although these tests are not absolute in their results, on the whole they are very useful.

Some Tests for Disease

Type of Test	Purpose of Test	How Test Is Made
Direct examination	To show presence of specific bacteria, such as tubercle bacilli, streptococci, and typhoid bacilli	Microscopic tests are made of body excretions, as feces, urine, pus, mucus, sputum (spū'tŭm).
Schick (shĭk) test	To determine whether a person is immune to diphtheria. All children, especially those of preschool age, should be given this test.	A small quantity of diphtheria toxin is injected into the arm. The appearance of a slight red spot some hours later is a sign of susceptibility.
Dick test	To determine whether a person is immune to scarlet fever	A small quantity of diluted toxin is injected into the skin of the forearm as in the Schick test. A red spot will appear on the skin if the person is susceptible to the disease.
Tuberculin test	To show presence of the active or dormant tuberculosis germs	A drop of extract of tubercle bacilli (old tuberculin) is injected beneath the skin of the arm. The presence of a dark spot appearing within a short time indicates the presence of the disease.
Widal test	To determine whether a person has typhoid fever. It is particularly valuable in diagnosing doubtful cases.	A few drops of blood from the patient are allowed to stand until the serum has separated. The serum is then diluted in a weak salt solution and living typhoid bacilli are added. If in an hour or less bacteria gather in clusters, the reaction is said to be positive. This means the antibodies are at work and indicates the presence of typhoid germs.
Wasserman test	To determine whether a person has syphilis. With the help of this test the physician can follow the activity of the germs and give proper treatment.	This is a very complex test and must be made by an expert. It is a blood test which shows whether or not protective substances have been formed. If these are found, germs of the disease are shown to be present.

Such tests make it possible to determine immunity to certain diseases, to diagnose diseases early enough to begin proper treatment, and to protect the community by quarantine.

Immunity of the future. Constant experimentation is being carried on in medical and bacteriological laboratories in all the civilized countries of the world. Each year brings to light some new method or weapon of defense with which to conquer our unseen foes, the microbes. For example, d'Hérelle (dā'rĕl'), a French Canadian working in the Pasteur Institute, thinks that he has discovered an ultramicroscopic body which instead of feeding upon the bodies of animals is destructive to disease-producing bacteria. He calls this organism the *bacteriophage* (băk-tē'rĭ-ô-fāj), and claims that it may be developed in a laboratory. It may be kept in tubes for months and used when needed to destroy a given kind of microbe. His findings, however, have not been demonstrated to the satisfaction of many scientists, and further investigations are being made.

We ought to be keenly interested in the progress that is being made in the great fight to produce immunity to disease. There are many unknown phases of the problem yet to be solved. It is a fascinating field and attracts some of the greatest scientists in the world.

Problem 4. How are diseases that are caused by pathogenic organisms combated by society?

The duty of society. Up to this point our discussion has been limited to the causes of disease, the transmission of disease, and the problem of immunity. It is highly important that we use this information to strengthen our defenses against disease. This, however, cannot be done satisfactorily unless we coöperate with others and consider the problems of community sanitation.

Practically every community, whether large or small, has made provision for the distribution of information pertaining to health. In most cities and towns branches of the government carry on activities relating to sanitation and health. The larger cities insist upon a careful inspection of water, milk, and food supplies. Health departments in counties and cities

handle such problems as quarantine, fumigation, inspection of housing conditions, and examination of school children. Every state and nearly every community have health codes filled with excellent ordinances drawn up for the protection of

AN UNFORTUNATE SITUATION

The absence of fresh air and sunlight in the crowded districts of large cities is favorable to the growth of dangerous microbes. These children live in a thickly populated district. They have left their crowded homes and have come into the street to play.

its citizens. If the provisions of these codes were followed and all the people of the community would coöperate in their enforcement, the battle against dangerous microbes would end in a happy victory.

A few phases of the problem of combating diseases by united social effort and a few of the important measures of control will be treated on the following pages. Since it is impossible to go into much detail at this point, it is suggested that various members of the class prepare special reports on any subjects that present particular problems in the local community. A class discussion will reveal what are some of the most important problems to be considered.

PRECAUTIONARY MEASURES

How quarantine helps us fight disease. The word *quarantine* comes from the Italian word *quaranta* (kwä-rän'tä), meaning "forty." During the Middle Ages a forty-day seclusion was demanded as a protection against the plague. Ships that came from countries where the plague was raging were detained for forty days by Italian cities before the passengers were allowed to land.

Today we know the causes of most diseases, which ones are communicable, how they are spread, and how lông it will be before the patient can mingle safely with others. Owing to our modern advanced knowledge concerning disease and improved sanitary conditions, methods of quarantine have been greatly changed. In fact, in the case of certain diseases, quarantine has been largely displaced by sanitation. It has been found that it is better to clean up the conditions responsible for sickness than to build walls around them. If a community could develop perfect sanitary conditions, there would be no need to fear typhoid fever, yellow fever, malaria, cholera, typhus, or bubonic plague. Likewise, if all the inhabitants of a community were vaccinated, there would be no need for quarantine as protection against smallpox.

Quarantine is commonly considered necessary to safeguard the people of a community against the spread of disease. Consequently every state in the Union requires certain periods of quarantine for communicable diseases. While under quarantine a patient must refrain from mingling with others, and other persons in his household must take reasonable care for the protection of the public. Among the diseases quarantined are smallpox, scarlet fever, mumps, whooping cough, typhoid fever, measles, diphtheria, and infantile paralysis.

Modern uses of fumigation. It was formerly thought that the germs of a disease, in a room or house where a person had been ill, could be destroyed by *fumigation,* that is, by burning sulfur, spraying formaldehyde, or using other fumes or gases. Recently, however, it has been determined that fumigation is not an effective means of eliminating danger. The difficulty

is that the fumes or gases do not penetrate the places where the germs really are. Many microbes are pressed into the floor coverings or into cracks in the floor or are contained in dried masses of sputum. Usually only the germs on the surface are killed by fumigation. The burning of sulfur or the releasing of prussic acid gas is very effective in warfare upon rats, vermin, and insects that carry germs. The prussic acid gas, however, is a poison that must be handled with care.

Terms associated with disinfection. *Disinfection* is any process that destroys disease germs or renders them harmless. Certain other terms often used in connection with this process are: disinfectant, germicide, antiseptic, deodorant, and sterilization. A *disinfectant* is a substance that kills disease germs or makes them inactive. A *germicide* is a substance that kills disease germs or other microörganisms. An *antiseptic* is a substance which retards or prevents the growth of disease-producing bacteria. *Sterilization* is the process of bringing about the complete destruction of germs, and is practiced to purify surgical instruments, barber towels, and many other things. A *deodorant* is used to absorb or to destroy noxious odors but usually has little effect in the destruction of germs.

Disinfection should be continuous. The theory of disinfection has materially changed during the last few years. Formerly cities spent large sums of money to enforce disinfection in homes where people had been ill with communicable diseases. Recent experiments have shown that microbes in the air die off very quickly, and that the greatest danger comes from contact with a person who is sick. This makes it quite clear that disinfection should be required during the time a patient is ill as well as immediately after his recovery. Bedding, towels, dishes, handkerchiefs, toilet articles, and clothing should be disinfected regularly during the illness. Likewise, all discharges from the patient's body should be immediately disposed of. If all these things are done, disinfection after the patient has recovered will be a relatively simple matter.

Types of disinfectants. There are two distinct types of disinfectants. Those made up of chemical compounds, such as

carbolic acid, bichloride of mercury, iodine, formalin, and "quicklime," are known as *chemical disinfectants.* Those that come from natural sources, as sunlight, or result from natural processes, as drying, are known as *natural disinfectants.*

The best disinfectants are provided abundantly by the forces of nature. Fresh circulating air and the direct rays of the sun spell death to many bacteria. We should roll up our shades, open our windows, and let nature's disinfectants permeate our rooms. Our bedding and clothes should frequently be hung out of doors in the sunlight. Then, too, we ourselves should spend much time in the open air. In these ways we can take the fullest advantage of the powerful disinfectants that are provided for us. Their value has been proved in the prevention and treatment of many diseases.

COMMUNITY SANITATION

The necessity for community organization. There was a time in our history when nearly every family lived in the country and produced most of its own food supply. All the garbage and waste materials around the home were fed to livestock. Human excrement was disposed of in such a way that there was little danger of contamination. Neighbors lived far apart; hence the possibility of an epidemic was rather remote. However, when families began to live closer together in towns and cities, a serious condition arose. The necessity for sanitary measures was not understood, and disease was found on every hand. This condition continued down to the time when microbe hunters identified the causes of disease. Since then the real value of sanitation has been determined, and tremendous progress has been made in the warfare against disease.

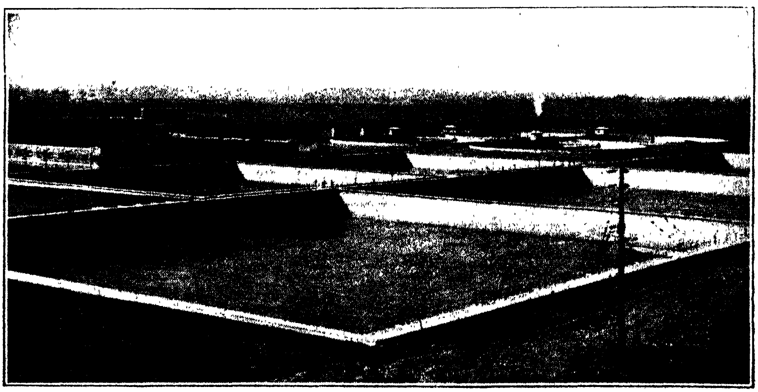
One of the most important functions of any local government today is that of eliminating the factors which produce and spread disease. The people in our towns and cities must have pure water and food supplies, particularly milk. They must make provision for the disposal of sewage, garbage, and rubbish. Since they ride together in buses and trains and gather in schools, churches, theaters, factories, and stores,

it is evident that the health of each individual is of concern to the whole community. If anyone becomes ill with a contagious or infectious disease, he must be isolated for the protection of all those around him.

How the water supply is protected. In rural communities where the water supply for the family comes from a well or a spring, the main problem is to prevent contamination by sewage. The water from a deep well is usually pure, but that from a shallow well should be tested from time to time to insure safety. There are several sources of community water supply. In smaller towns and cities it is usually pumped from deep wells. In large cities it usually comes from rivers or lakes, and we naturally wonder how water contaminated with dirt, sewage, and other wastes can be made clean and safe. We are all the more curious when we find that some of the larger communities use millions of gallons daily.

There are many different methods of purifying water. A common and effective way is to strain it through beds of mixed sand and gravel. This process filters out the dirt and most of the germs. If the water contains a great quantity of suspended matter, chemicals, such as a combination of lime

WHEN BACTERIA MEET AN ENEMY



Ewing Galloway

This picture illustrates one of the most common methods of purifying water. The water is run through large beds of sand and gravel. The sand and gravel remove the bacteria and cause many of them to be killed through exposure to sunlight.

and aluminum sulfate, may be added to cause the suspended matter to settle to the bottom. If tests then indicate that the water is still unsafe, liquid chlorine or other germicide may be added. The addition of a germicide does not greatly affect the taste and is not harmful to the body.

The disposal of sewage. Human excrement and other wastes from homes and factories must be disposed of in such a way as to protect the public health. In rural communities or sparsely settled areas, the problem is not difficult. Outside toilets should be so constructed that they will be free from flies and other animals and the sewage will not contaminate the water supply. If proper provision is made for the disposal of sewage and there is a good supply of pure water, the country is indeed a very healthful place in which to live.

The sewage of some small communities is emptied into large bodies of water, as rivers and lakes, without producing harmful results. As it mixes with the water, the germs are killed from exposure to the sun and air. In other communities, especially larger ones, the sewage is treated in disposal plants to make it harmless. It is carried from homes and factories to disposal plants through pipes or sewers laid beneath the surface of the ground. After it has been disinfected at the disposal plants, it is discharged into rivers or lakes without endangering public health. Proper treatment of sewage is one of the most important factors in sanitation.

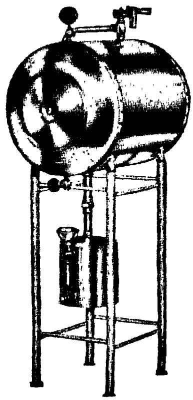
The disposal of garbage and refuse. Another matter that is given special attention in most cities is the removal of garbage, rubbish, ashes, and dirt. Garbage wagons go from home to home for the purpose of collecting garbage. Some cities maintain incinerators for the destruction of garbage. Others maintain plants for extracting fats from the animal matter in garbage. These fats are often sold for making soap. The solids left after fats are removed are used as fertilizer.

The streets of most cities are cleaned frequently and during the summer are sprinkled with water or are oiled. These steps are necessary to remove and destroy the millions of microbes that are found in the accumulated dust and dirt.

Problem 5. What laboratory techniques are used in the study of bacteria?

Equipment for bacteriological study. To catch bacteria and study them, special equipment is necessary. For elementary bacteriological work the following materials will suffice:

THE AUTOCLAVE



Courtesy Chicago Apparatus Company

Certain spore-forming bacteria readily withstand the temperature of boiling water, or 212° Fahrenheit. Consequently they are subjected to heat under the pressure of steam, ordinarily fifteen or twenty pounds, corresponding to a temperature of about 245° Fahrenheit.

1. *Glassware*—flasks, beakers, test tubes, Petri (pē′trĭ) dishes, and funnels.
2. *Culture media*—bacterial food. Either a mixture of beef extract and gelatin or beef broth and agar-agar (ä′gär) may be used.
3. *Sterilizing apparatus*—steam sterilizer (autoclave), Bunsen burner.
4. *Other materials*—absorbent cotton, platinum needle, pipettes, stains, cover glasses, slides, and microscope.

The chief aid in the study of bacteria is, of course, the microscope. Before bacteria may be examined, however, they must be caught and prepared. Earlier in this unit we learned where they may be obtained. The important problem now is how to "trap" them and prepare them for study.

HOW TO CATCH BACTERIA AND STUDY THEM

A student's description of his beginning work in the fascinating and important field of bacteriology follows.

My Experience in a Bacteriological Laboratory

Preparing the bacteria "traps." When I first started to work in the bacteriology laboratory, I felt as if I were working in a home economics class. We spent the first week washing and scrubbing test tubes, Petri dishes, flasks, boilers, and other equipment. After the glassware was scrubbed with soap and water, it was run through a powerful disinfecting solution. The test tubes and flasks were

plugged with cotton, lids were put on the Petri dishes, and everything was placed in a steam sterilizer for about an hour. The sterilized equipment was then carefully put away until it was needed.

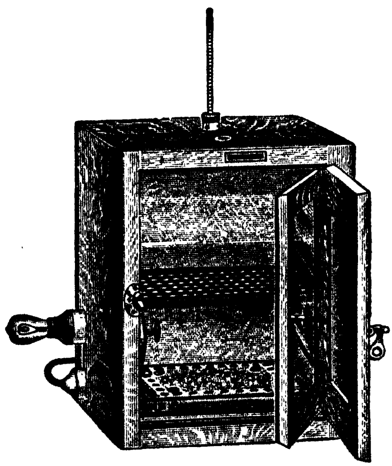
During the following week we engaged in cooking. It was amusing to see a group of young men in shirt sleeves, wearing aprons, dashing here and there like brides attempting to cook their first meals. The purpose of this work was to prepare a culture medium or bacteria food, sometimes known as nutrient agar, upon which the bacteria were to be grown. This was done by adding 7½ grams (about ¼ ounce) of agar-agar, a jelly-like substance obtained from seaweed, to each 500 cubic centimeters (about one pint) of hot filtered beef broth. Enough baking soda was added to make the mixture slightly alkaline, after which it was boiled and then filtered two or three times through several layers of moist absorbent cotton into sterilized flasks. These flasks were then plugged with non-absorbent cotton and left for an hour at a temperature of 212° Fahrenheit in a steam sterilizer. This was the last step in the preparation of the culture medium and it was finally ready for use. In every step it was necessary to proceed very slowly so as not to slight anything. This was especially true of sterilization, for every time a culture medium is exposed to the air, or the materials to be used in handling bacteria are exposed, they *must be sterilized.*

Trapping our victims. When the dishwashing, cooking, and sterilization of the materials were completed, we were ready for the real fun and excitement of trapping our victims. The first laboratory exercise was designed to show how prevalent are unseen forms of life. To catch our victims the following "traps" were set:

1. *a.* The culture medium in a Petri dish was exposed two minutes in the corridor while the classes were changing.
   b. The culture medium in a Petri dish was exposed two minutes at the same place in the corridor thirty minutes after the classes had changed and when no students were present.
2. *a.* A few drops of distilled water were placed on the surface of the culture medium in a Petri dish.
   b. A few drops of regular drinking water were placed on the surface of the culture medium in a second Petri dish.
   c. A few drops of water from a possibly contaminated source, in this case a lake, were placed on the culture medium in a third Petri dish.

3. A small quantity of milk was diluted with distilled water and a few drops were placed on the culture medium in a Petri dish.
4. A "typhoid" fly walked across the culture medium in a Petri dish.
5. A human hair was placed on the culture medium in a Petri dish.
6. A student who had just washed his hands touched his finger tips to the surface of the culture medium in a Petri dish.
7. A dollar bill was soaked in distilled water in a sterilized test tube, and a few drops of the water were placed on the culture medium in a Petri dish.
8. The culture medium in a Petri dish was touched to a doorknob.

THE ELECTRIC INCUBATOR



Courtesy W. M. Welch Manufacturing Company

This constant-temperature oven is used for incubating bacteria.

Similar exposures were made to many other things, such as vegetables, fruits, meats, and the air of city streets, classrooms, and factories. The dishes of exposed culture media were next numbered, labeled, and placed in an incubator, where they were kept at a temperature equal to that of the human body (98.6° Fahrenheit) for about forty-eight hours. We were then ready to examine the culture media in the various Petri dishes to find out from which of the sources we had trapped bacteria. The table on the opposite page gives a collective picture of what we observed on the dishes.

How bacteria were isolated and identified. Since a colony of bacteria had developed wherever a single bacterium was deposited, we often found many different kinds of colonies in the same culture medium. They were different in size, shape, and color, and some of them overlapped one another in the same dish. A culture medium containing several different kinds of colonies is called an *impure culture.* In order to study the characteristics of one particular kind of bacterium, it was necessary to prepare a *pure culture.* We did this by the process of *isolation.* First we sterilized a platinum needle by passing it through a flame. We then dipped the needle

into the colony we wanted to study and passed it lightly over an unexposed sterilized culture medium in another dish. This was covered immediately to prevent other bacteria from entering. If under the microscope we discovered that we had failed to secure a pure culture, the whole process of isolation had to be repeated. Sometimes it was necessary to try several times before we obtained a culture medium that contained only one kind of bacterium.

What Some of the Petri Dishes Revealed

Nature of the Exposure	Result Following Incubation
1. *a.* The corridor during change of classes	Entire surface was dotted with colonies of bacteria of different shapes, sizes, and colors. A colony formed wherever dust particles fell upon the culture medium.
b. Same place thirty minutes after classes had passed	Few small colonies
2. *a.* Distilled water	No colonies
b. Drinking water	Few small colonies
c. River water	Many large colonies
3. Unpasteurized milk	Many large colonies
4. Feet of fly	Colonies developed at each impression of fly's feet
5. Human hair	Colonies along each side of the hair
6. Finger tips of washed hands	Colonies wherever finger tips touched the culture medium
7. Rinse water from dollar bill	Colonies profusely scattered over the surface
8. Doorknob	Large colonies where the doorknob touched the culture medium

A Study of the Colony as a Means of Identification

Certain characteristics of a colony aid in the identification of bacteria. Among the most important are the following:

1. *The shape.* Some colonies have smooth edges, some scalloped edges, and some fringed edges.
2. *The color.* Bacteria are characterized by different pigments and may produce red, yellow, purple, green, or white colonies. These colors, however, may be affected by oxygen, temperature, food, antiseptics, and light.

3. *The manner of growth,* or the effect of the bacteria on the culture medium. Some bacteria cause the medium to liquefy; others cause gas to form. Some colonies appear only on the surface of the medium; others grow within it. Some are opaque in appearance; others are glistening.

THE MICROSCOPE AS AN AID IN IDENTIFYING BACTERIA

Even though bacteria are microörganisms, they have certain distinguishable characteristics when observed under the microscope. It is largely through these features that they may be identified. Among the leading characters are:

1. *Size.* Bacteria vary greatly in this regard. The largest bacillus is 50 to 60 microns long and 4 to 5 microns wide. One of the smallest forms known, *Bacillus influenza,* is about 1/2 micron long and 1/5 micron wide.
2. *Shape.* There are three basic forms of bacteria, the spherical, the rodlike, and the spiral, all of which have been pictured and described. The *Bacillus tetanus* has a spore at one end which gives it a characteristic drumstick appearance. Some of the cocci form in chains.
3. *Motility.* Certain bacteria, such as *Bacillus typhosus,* have the power to move about. They do this by means of flagella and vary in their movement, some dancing or trembling and others whirling about.
4. *Staining qualities.* Some kinds of bacteria, as the tubercle bacillus, are known as acid-fast because they retain coloring so well. Usually such bacteria take up stain very slowly, but hold it so well that even washing with an acid solution will not remove it.

Problem 6. Who are some of the dramatic figures in the development of techniques for the control of disease?

If we compare the progress in the conquest of disease before the time of Leeuwenhoek with the progress after his time, we can readily appreciate the tremendous importance of his contribution to mankind. Strange to say, however, very little

was done in the battle against disease during the first hundred years after his death. The next important step came with the discovery of microbes and their relation to disease.

WARRIORS IN THE BATTLE AGAINST DISEASE

We shall now consider a few of the notable scientists who have helped to enlighten the world in the battle against disease. These scientists have delved into many different fields, each making a definite contribution to mankind.

THE FATHER OF BACTERIOLOGY

Louis Pasteur (1822–1895). The master mind of all microbe detectives is the great biologist Louis Pasteur (pȧs′tûr′). His list of contributions to the welfare of mankind is so great that we can consider only his greatest achievements. He was born in southeastern France in 1822, and first attracted attention for his work in the field of chemistry. While making certain studies for the wine growers and brewers of France, he discovered that tiny yeast germs cause fermentation. Along with the yeast germs in some of the wines and beer, however, he observed numerous other tiny living objects that attracted his interest. His curiosity was aroused, and he concluded that these tiny cells, which were later called bacteria, might be the cause of disease.

LOUIS PASTEUR, THE "FATHER OF BACTERIOLOGY"

This picture shows the scientist in his laboratory, where he accomplished many notable results.

In his further experimental work Pasteur found that, by heating wines and beer for a short time to a point somewhat below boiling, he could kill undesirable bacteria and yeasts. This process, now known as *pasteurization,* is used extensively today in the preparation of canned foods and in the preservation of milk for market.

How Pasteur saved the silk industry of France. A few years after his notable discoveries of fermentation and pasteurization, Pasteur was called upon to do another important piece of work. A disease of unknown origin was killing silkworms in France and causing great financial loss. In 1865 the government of France appealed to Pasteur to do what he could to save the industry. He grappled with the problem for several years. His efforts were rewarded when he discovered the microbe that was causing the silkworms to die. Never before had a specific microbe been related to a disease. It was from this beginning discovery by Pasteur and later ones by Koch, a German, that there came into existence a new branch of biology now known as *bacteriology.*

How Pasteur paved the way for future immunization. The entire effort of Pasteur from the time of his discovery of microbes to the end of his life, in 1895, was devoted to finding the causes of diseases and to producing substances effective in curing them. It was in these fields that he rendered his greatest service to mankind. The techniques he developed laid the foundation for all future work in the improvement and use of vaccines, serums, and antitoxins.

Pasteur did his first experimental work with chickens in an attempt to determine the cause of cholera. He took disease-producing bacteria from a sick chicken and obtained a weakened suspension of the bacteria by growing them in a culture medium. A small quantity of the "attenuated" or weakened suspension of the bacteria was then injected into a well chicken. As a result the well fowl contracted a mild form of the disease. Pasteur later followed the same procedure in working out the cause and cure of swine fever and of the deadly anthrax, a disease which attacks both animals and man.

How Pasteur developed the treatment for "mad dog" bites. Pasteur next turned to hydrophobia or rabies, the "mad dog" disease, which was one of the most dreaded of all the diseases of his time. Again he was successful. He began by injecting the virus of hydrophobia into rabbits. Since the disease attacks these animals largely in the spinal cord and brain, he was able to get a greatly weakened virus by removing the spinal cords of inoculated rabbits and slowly drying the tissues. When he injected this weakened virus into dogs, they became immune to the disease. His next problem was to discover whether human beings could be rendered immune in the same way. He soon had a chance to find out, for on July 6, 1885, a young lad who had been bitten by a mad dog was brought to his laboratory. In spite of all his successes, Pasteur was very loath to experiment on this boy; but to do so might save his life. Consequently he carefully administered fourteen injections of virus to the lad and awaited results. Not a sign of the disease appeared. Another great victory had been won in the warfare against disease.

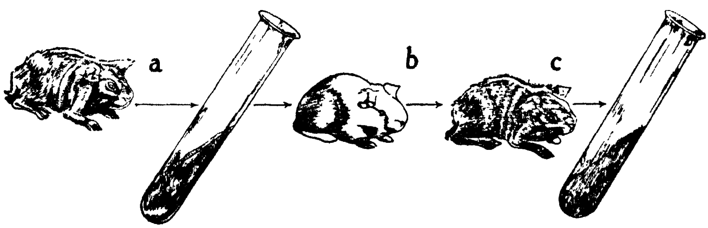
The dramatic episode that led to the founding of the Pasteur Institute. One of the most dramatic episodes in Pasteur's life was his treatment and cure of sixteen Russian peasants who were suffering from hydrophobia. Five of the patients were so badly mangled that they could not walk. Furthermore, the situation was discouraging because two weeks had passed before treatment was started. Everybody thought the patients would surely die. Pasteur worked feverishly with them. Each morning and night he administered injections of vaccine —twice as often as he had ever given them before. Despite their desperate condition all but three of the peasants recovered. This triumph over disease brought to Pasteur a shower of praise from all the civilized countries in the world. Millions of francs were provided with which to build in Paris a great laboratory by means of which he might continue his work. It was in this way that the Pasteur Institute was founded. Today it stands as a tribute to his great work and is one of the leading institutions in the world warring against disease.

The Pasteur of Germany

Robert Koch (1843–1910). Another great microbe detective who merits recognition along with Pasteur is Robert Koch, a German. It was Koch who made bacteriology an exact science. He developed a technique for studying bacteria by adding gelatin to nutrient fluids to obtain solid culture media. Bacteria previously had been grown in liquids and consequently were difficult to isolate.

Koch made a further contribution to microscopic work by perfecting a method of fixing microbes to a glass slide by drying. Then by staining the microbes blue or red he found they could be studied more minutely and could even be photographed. In 1882 he discovered the germ that causes tuberculosis, which is sometimes referred to as Koch's bacillus.

HOW KOCH IDENTIFIED A SPECIFIC ORGANISM AS THE CAUSE OF A GIVEN DISEASE



(a) Germs were taken from a sick animal and used in growing a pure culture.
(b) A well animal was inoculated with germs from the pure culture.
(c) The well animal then showed symptoms of the disease. The disease was further identified by means of a pure culture taken from the inoculated animal.

The procedure which Koch followed in his investigation of an unknown disease involved certain steps commonly known as Koch's postulates or rules. The method is still used, and guards against hasty and erroneous conclusions. The four important steps in Koch's procedure are:

1. To assume that specific germs are present in an animal suffering from a disease
2. To secure some of the germs and develop a pure culture of them in an artificial medium
3. To transfer the germs from the pure culture to a well animal and observe whether they will produce the disease.

If the symptoms of the disease appear, there is no question as to the cause and the identity of the germs

4. To identify further the germ-producing organism by studying a pure culture from the inoculated animal

The Founder of Antiseptic Surgery

Sir Joseph Lister (1827–1912). Another benefactor of mankind was Lord Lister, who made a notable contribution in the field of surgery. It was in 1867, while he was a professor of surgery in the University of Glasgow, that Lister first experimented with the use of carbolic acid in the treatment of wounds. Previous to that time there was always grave danger that gangrene or blood poisoning would develop after an operation. In the beginning Lister applied concentrated carbolic acid directly to the wound. This method was successful, but exceedingly painful, and often resulted in large, ugly scars. To overcome this result, Lister saturated silk gauze with the acid and applied the gauze to the wound. He found this plan much more successful, but sometimes he ran into difficulty because of the threads. Therefore he experimented with materials that could be absorbed. At first he tried the blood vessels of calves and the small intestines of sheep. Later he adopted catgut treated with sulfur and chromium.

In 1869 Lister turned his attention to the destruction of harmful bacteria in the air. Before he performed an operation, he sprayed the atmosphere with a weak solution of carbolic acid. After he had used this method for a time, he decided that a more efficient method would be to sterilize everything used in the operation itself. His next step, therefore, was to develop a technique for using antiseptics on the hands, dressings, sponges, bandages, and surgical instruments. As a result of all these efforts, surgical practices have been completely revolutionized and thousands of lives have been saved.

The Conqueror of Smallpox

Edward Jenner (1749–1823). The first person to place vaccination on a sound basis was Edward Jenner, an English

physician. While Jenner was still a young medical student, he learned that a certain milkmaid could not have smallpox because she had already had cowpox. He was so interested in the situation that he began an intensive study of smallpox and its prevention. He began his study about the year 1775. At first his findings were somewhat confusing. Finally he arrived at the conclusion that cowpox existed in two different forms, only one of which served as a protection against smallpox. He found further that this form of cowpox served as a protection only when administered at a certain stage of the disease.

Jenner's work was handicapped by the fact that there were few cases of cowpox near his home and he had little chance to test his theories. In 1796, however, he took some pus from the hand of a person suffering from cowpox and injected it into the arm of an eight-year-old boy. Six weeks later he inoculated the boy with the germs of true smallpox and no disease resulted. This experiment provided the first case of artificial immunity. Although Jenner was now convinced that immunity could be established, he hesitated to announce his findings. Finally, in 1798, he wrote a paper in which he announced his discovery to the world. As a result of his experiments, smallpox today is completely under control, and prevention of the disease is simply a matter of vaccination.

Jenner also made contributions to several other fields of science. He was especially interested in zoölogy and geology, making valuable studies in both of these fields. Strangely, too, he constructed the first balloon in his part of England. He will be remembered chiefly, though, for his outstanding work in connection with vaccination.

Who's Who among the Microbe Detectives

Many other names could be added to the list of those who have aided in the conquest of disease. It is interesting to note that men from all parts of the world have made contributions. The following table will show that many different nations have been united in this one great battle.

Name	Country	Contribution to Conquest of Disease
Leeuwenhoek....	Netherlands.....	First pictured bacteria and described them as little animals seen in rain water, saliva, and putrefying material. Provided the microbe detectives with their most powerful weapon, the microscope.
Jenner..........	England.........	Perfected vaccination.
Pasteur.........	France..........	Related specific microbes to diseases of both plants and animals. Perfected the treatment for rabies, or hydrophobia.
Koch...........	Germany........	Developed techniques for laboratory procedure in bacteriology. Discovered the germ causing tuberculosis.
Metchnikoff.....	Russia..........	Discovered white corpuscles and their functions.
Lister...........	England.........	Developed antiseptic surgery.
Ehrlich.........	Germany........	Studied the blood and its relation to immunity to certain diseases.
Roux...........	France..........	Discovered diphtheria toxin and developed antitoxin treatment for diphtheria.
Noguchi........	Japan...........	Identified the parasite of yellow fever.
Reed and Lazear	United States....	Discovered the relation between the mosquito and yellow fever.
Howard........	United States....	Demonstrated the relation of the common fly to disease (especially typhoid).
Carrel..........	United States....	Developed methods of wound antisepsis.
Flexner.........	United States....	Developed modern serum and antitoxin treatments.

SUGGESTED ACTIVITIES

I. Self-Organization Summary

A. Microbes and Their Habits

1. How can you tell the difference between plant and animal microbes?
2. What different shapes are found among bacteria? Give examples of each.
3. Describe conditions favorable and unfavorable to the growth of bacteria.

B. Diseases Caused by Microbes

1. Group germ diseases according to methods of spreading.

2. Discuss four major diseases from the standpoint of the characteristics of the germs that cause them and the methods of prevention.
3. Explain how the Anopheles mosquito causes malaria in man.

C. How the Body Fights Disease
1. How do phagocytes fight bacteria?
2. What are antibodies, and how do they help in the protection against disease?
3. Explain how acquired immunity to several diseases may be produced.

D. Community Control of Disease
1. Discuss the value of each of the following methods of controlling disease: fumigation, disinfection, and quarantine.
2. What services must a community render to protect the health of its people?

E. How Microbes Are Studied
1. Describe the steps involved in capturing, growing, isolating, and identifying microbes.

F. Famous Microbe Hunters
1. Explain the important contributions of Pasteur, Koch, Lister, and Jenner.
2. What contributions worthy of note have been made by other scientists?

II. Laboratory Studies

A. Prepare and examine cultures of yeasts, molds, and bacteria. Directions for growing and studying bacteria are given in Problem 5.

B. Observe the feet and wings of a housefly, using the low-power objective of the microscope. Note the adaptations which make it dangerous as a carrier of disease (hairs and sticky foot pads).

C. Plot curves from the health statistics of your community to show the relation of the various seasons of the year to mortality rates.

III. Display Posters. This unit affords many opportunities for making large display charts containing such valuable data as:

A. Sketch of a water purification system

B. Skétch of a sewage disposal plant

C. Diagram of the life cycles of disease organisms having alternate hosts, such as those responsible for malaria and bubonic plague

D. Lists of (1) all diseases for which immunity has been developed; (2) all ways in which bacteria gain entrance to the body, with examples

E. Lists of disinfectants, fumigants, and antiseptics with statements of their relative values.

IV. **Field Trips.** The following field trips will be found particularly helpful in a study of this unit:

A. To the water works for the purpose of obtaining information about the methods of purification in use in your own community

B. To a modern dairy for the purpose of observing the methods used to protect your milk supply

C. Into your community for the purpose of making a sanitary survey. Locate all unfavorable conditions which you know, from the study of this unit, will endanger the health of the people. Such a survey may point the way to a general clean-up and to certain permanent improvements in the sanitary conditions of the community

V. **Special Reports.** The following is a list of suggested topics:

A. Pathogenic yeasts and molds

B. The use of vaccines, serums, antitoxins (choose one)

C. Sewage disposal, garbage collection and disposal, street cleaning, and food inspection, together with recommendations for improvement when it appears necessary (These topics should always be planned so that they apply to local situations.)

D. Any disease not discussed in the text, perhaps one that has appeared in the local community

E. Federal quarantine

F. Any phase of modern methods of fighting germ diseases in which you may be interested

G. Brief summaries of interesting articles or books treating the subject of disease. *The Conquest of Disease*, *Who's Who among the Microbes*, *Microbe Hunters*, and other good books are listed in the references for this unit.

REFERENCES[1]

1. Calkins, Gary N. *The Smallest Living Things.*
   a. Filterable viruses, pp. 14–16
   b. Spirochetes, pp. 23–31
   c. The border line between plants and animals, pp. 42–47
2. De Kruif, Paul. *Microbe Hunters.*
   a. First of the microbe hunters, pp. 3–37
   b. Microbes are a menace, pp. 57–105
   c. Pasteur and the mad dog, pp. 145–184
3. Kopeloff, Nicholas. *Man versus Microbes.*
   a. How microbes are studied, pp. 43–54
   b. Bacteriophage, pp. 197–201
   c. Disease-producing Protozoa, pp. 214–225
4. Park, William H., and Williams, Anna W. *Who's Who among the Microbes.*
   a. How microbes become better known, pp. 17–36
   b. How microbes live and act, pp. 36–51
   c. Family relationships of microbes, pp. 69–84
   d. The spirochetes, pp. 214–219
   e. Animal microbes, pp. 239–252
   f. Unknown microbes, filterable viruses, pp. 252–272
   g. Protection against disease germs, pp. 273–297
5. Rice, Thurman B. *The Conquest of Disease.*
   a. The scientific conquest of transmissible disease, pp. 17–30
   b. The cause of transmissible disease, pp. 30–39
   c. Infection and resistance, pp. 39–51
   d. How we catch disease, pp. 51–61
   e. The insect-borne diseases, pp. 223–257
   f. Diseases transmitted by contact, pp. 260–304
   g. The means by which transmissible diseases are controlled, pp. 317–359
6. Tobey, James A. *Rider of the Plagues.*
   a. Great plagues of the past, pp. 3–24
   b. The antiquity of sanitation, pp. 28–50
   c. Pasteur, pp. 80–163
   d. The conquest of yellow fever, pp. 163–191
   e. Trudeau and tuberculosis, pp. 193–219

[1]The pages listed here are those found in the editions indicated in the alphabetical list of references given at the end of this book.

7. Zinnsser, Hans. *Rats, Lice and History.*
    - *a.* Parasitism in general, pp. 57–77
    - *b.* New diseases, pp. 77–105
    - *c.* Diseases of the ancient world, pp. 105–150
    - *d.* Influence of disease on military history, pp. 150–166
    - *e.* On the louse, pp. 166–189
    - *f.* Much about rats, pp. 189–212
8. *Book of Popular Science, The.*
    - *a.* On the microbe's track, Vol. 10, pp. 3457–3463
    - *b.* Man's most deadly enemy—tuberculosis, Vol. 11, pp. 3561–3570
9. *Compton's Pictured Encyclopedia.*
    - *a.* Vaccination, Vol. 14, p. 267
    - *b.* Man's deadliest foe—the microbe, Vol. 6, pp. 77–80
10. *New Wonder World, The.*
    - *a.* The work of Lord Lister, Vol. 4, pp. 393–394
    - *b.* The fight against yellow fever, Vol. 4, pp. 394–396
11. *World Book Encyclopedia, The.*
    - *a.* Sewage and its disposal, pp. 6511–6514
    - *b.* Bacteria and bacteriology, pp. 566–569

VISUAL AIDS

FILMS (16 mm.)

A. The Y.M.C.A. Motion Picture Bureau, 347 Madison Avenue, New York City, or 19 South LaSalle Street, Chicago, Illinois.
   1. Man against Microbes. 1 reel, silent, free.
      Presents 300 years of progress in public health
   2. Conquest of Diphtheria. 1 reel, silent, free.
   3. Mosquito Control. 1 reel, silent, free.

B. Eastman Teaching Films, Inc., Rochester, New York.
   1. Bacteria. 1 reel, silent, $18.00.
      Shows a culture medium and traces the growth of cocci, bacilli, and spirilla
   2. Tuberculosis and How It May Be Avoided. 1 reel, silent, $24.00.

C. University of Chicago. Biological Science Service, Chicago, Illinois.
   1. Body Defenses against Disease. 1 reel, sound. Apply for rate.

CHARTS

A. Series Schmeil Botany. Title: Bacteria. No. 13.

UNIT FOUR

ALLIES IN KEEPING HEALTHY

SUGGESTIONS TO THE TEACHER

In spite of the remarkable progress that has been made in diagnosing, preventing, and curing disease, people are often extremely negligent of their health. Strangely, they are exceedingly cautious when purchasing a home, a motor car, or articles of clothing, but they are almost deaf to expert advice concerning their health. Their attitude is all the more difficult to understand in view of the many agencies that are ready to help in the preservation of health and in the scientific treatment of disease. There is scarcely a home in the land that is not within reach of one or more reputable physicians.

The purpose of this unit is to impress upon young people the importance of tested scientific procedure in relation to health. To state it another way, the purpose is to help them to understand the slogan of the true scientist, "Not *who* is right, but *what* is true." Fortified with such a belief, they should hesitate to imperil their health by the acceptance of questionable practices or the use of questionable medicines.

OBJECTIVES

I. Facts and principles

- A. To explore unscientific practices that have resulted from superstitious beliefs and reliance upon medical fakers
- B. To learn about the contributions of leading scientists to the conservation of health

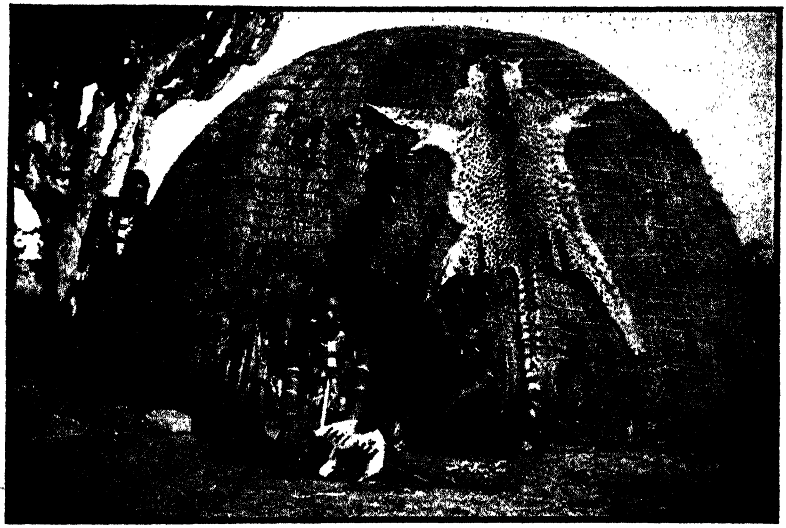
II. Attitudes

- A. To develop a favorable attitude toward scientific procedure in the maintenance of public health
- B. To show a willingness to rely on the advice of properly trained health authorities
- C. To develop an individual sense of responsibility for keeping physically fit

UNIT FOUR

ALLIES IN KEEPING HEALTHY

LOOKING TO MAGIC FOR THE CURE OF DISEASE



Ewing Galloway

The woman at the right is a witch doctor. The man seated beside her is a patient who has come for help. The witch doctor is pretending to drive out the demons of disease.

MAGIC HEALTH

PREVIEW

Have you ever heard older people tell about the medicine shows that were common in this country a few years ago? Like circuses, these shows went from town to town or from city to city, accompanied by "barkers" to shout the merits of their wares. Usually they carried gaudy paraphernalia with which to impress the public. The showmen made astonishing claims for the effectiveness of their cure-alls, and rarely did they fail to profit from the good nature or the ignorance of those who

stopped to look and listen. Fortunately, medicine shows are nearly a thing of the past. The showmen and their so-called remedies would today be considered humbugs by most people, though even now peddlers of "magic potions" may still be seen on the street corners in some of our larger cities.

In order that you may have a picture of the ridiculous performances and claims of actors in the medicine shows, the following play, which was written and produced by the members of a biology class, is quoted. It is frankly a burlesque; but it calls your attention to the fact that some people allow themselves to be misled rather than avail themselves of the services of men scientifically trained in the field of medicine.

"DR." KURALL'S MAGIC OIL

CAST OF CHARACTERS

"DR." KURALL, wearing a black cutaway coat, black trousers, high-top hat, and carrying a cane

CHIEF POW-WOW, wearing an Indian headdress, and a blanket wrapped about his body

SAMSON THE STRONG MAN, wearing a tight-fitting shirt stuffed out to give the effect of muscular development

"Dr." Kurall. Ladies and gentlemen, we are here today in your wonderful town to show you the road to health and happiness! Why be worried by asthma, cancer, tuberculosis, heart trouble, and halitosis, when inside of three weeks — think of it, in three weeks! — with the aid of this wonderful medicine [*raises bottle of medicine*] you may be completely cured? No matter how serious your case, this will relieve you from suffering and disease! Folks, to show you [*points at audience with cane*] how wonderful our medicine is, I will read you one of the many letters I have received from my grateful and appreciative patients. [*Takes out letter and reads:*]

DEAR DR. KURALL:

For ten years I was troubled with cancer and chronic lumbago. Nothing gave me any help until I discovered your wonderful magic oil. A few bottles cured me thoroughly and made a new man of me.

Yours in health,
(*Signed*) A. NONYMOUS

[*Folds letter with a flourish, and looks at audience as if to say, "I told you so."*]

Folks, you are not enjoying life when you are sick. You owe it to your loved ones and to yourself to be well and happy, especially now that you have a good opportunity. With the aid of this [*holds up bottle*] the poor as well as the rich may become healthy and strong. Ladies and gentlemen, I will now introduce Chief Pow-Wow, who will relate how, by using my magic oil, he became healthy and strong as you see him today. [*"Dr." Kurall bows to the chief.*]

[*As the chief speaks, "Dr." Kurall imitates the weird music of the tom-tom by hitting an empty box.*]

Chief Pow-Wow [*speaks in flat, even tones, without a smile*]. Paleface brothers, I have come to you with message and blessing of Great Spirit [*points to the ceiling*]. This message be medicine which we have here. I have get this message ten years [*holds up six fingers*] from great-great-grandfather. I give blessing with each bottle and *only* with each bottle. [*Goes through several motions and mutters a few words from an Indian tongue, signifying an Indian blessing.*]

"Dr." Kurall. Ladies and gentlemen, you have heard what Chief Pow-Wow says about this wonderful medicine. I will next present to you a man who was a mere weakling before he heard about this famous remedy. He will tell you how this precious liquid made him the strongest man in the world. Here he is, friends—Samson the Strong Man.

Samson the Strong Man. Ladies and gentlemen, a few years ago I wasn't the man you now see before you. Why, I couldn't even carry a basket of groceries from the store without breaking down. Then I came upon this man [*points to "Dr." Kurall*], and he saved my life. If you only knew what he is trying to do for you! See what he did for me [*slaps himself on the chest and coughs strongly*]. If it had not been for this man [*again points to "Dr." Kurall*] and his wonderful medicine, I'd be the weak individual that I used to be [*shakes head thoughtfully*]. He cured my tuberculosis and kidney trouble. See my muscles—all these I owe to "Dr." Kurall.

"Dr." Kurall. Ladies and gentlemen, you have just heard from Samson the Strong Man, and I know you are thoroughly convinced that this is the most wonderful medicine in the world. When you hear the price, you will be astonished! I won't say five dollars, four dollars, or even three dollars, but—two dollars! For the sum of two dollars we are giving away a bottle of health. Folks, while Samson passes through the audience to deliver your medicine, the chief will sing an Indian song in his native tongue and I will accompany him on the tom-tom.

Of course you would not be one of those to try "Dr." Kurall's magic oil. Do you always, however, apply scientific treatment to the care of your body? Are you acquainted with the various allies of health that you may command in the fields of medicine and related sciences? The following problems are presented to help you answer these questions.

PROBLEMS

1. **How have witchcraft, superstitions, and fakes played a part in the treatment of disease?**
2. **How have the science of medicine and the practice of surgery developed?**
3. **What are some of the more important modern scientific methods of treating disease and injury?**

Problem 1. How have witchcraft, superstitions, and fakes played a part in the treatment of disease?

PRIMITIVE METHODS OF TREATING DISEASE

Superstitions and weird healing practices. Most uncivilized peoples do not understand the nature of disease, nor do they have any knowledge of the structure and functions of the various organs of their bodies. They attribute all sickness to witchcraft or to supernatural causes. If a man is ill, they call in a so-called medicine man or witch doctor, hoping that he will be able to drive out the disease by magic. The witch doctor arrives dressed in hideous feathers, paint, bits of fur, bone necklaces, and earrings. He looks at the patient and pretends to remove a stone, bone, or other object that represents a disease.

Sometimes the uncivilized think of a disease as a demon. In such a case, the witch doctor pretends to drive out the disease by beating drums, burning plants with strong odors, and otherwise making the patient uncomfortable. The theory is that if he makes the demon uncomfortable it will leave.

Superstitions continued until man made certain scientific discoveries about the real causes of disease. Then many of the early superstitions and fears began to pass away. Strange to say, however, people were very slow to accept a scientific treatment of disease. Although they began to understand that disease was not caused by a demon, they did little about it. They failed to realize that every disease has a specific cause and requires a specific remedy. As a result of this testimony, cure-alls were produced and much quackery arose.

The tendency to believe in a common cause for disease naturally leads to a belief in common cures. This explains why medical fakers have flourished and why they have inflicted themselves upon the public. Down through the years they have brought about a tremendous loss. This loss is not confined to dollars and cents but includes a great toll of human life. One reason is that a person who takes a cure-all often delays proper treatment of his illness so long that medical science can no longer help him.

Specific diseases and their so-called cures. Fortunately, the medical faker is fast losing ground. Many so-called remedies of the cure-all type, however, are still offered for sale. To enter upon a detailed discussion of them would require much more space than we can allow in this book. A mere mention of some of the diseases for which cures are advertised will give an idea of their kind and number.

Recent investigations of the American Medical Association show that so-called cures for rheumatism are especially numerous, there being approximately two hundred fifty on the market. The findings also show that there are many "preventatives" for influenza, most of which flooded the market after a serious epidemic a few years ago. Deafness, epilepsy, cancer, goiter, and diabetes are other diseases for which dozens of cure-alls are sold. Many people suffering from such chronic diseases as asthma, catarrh, or tuberculosis, as well as people subject to periodic colds and headaches, yield to the extravagant claims for remedies. These remedies may temporarily allay suffering, but they do not curb the disease. Too often

such people are misled into the belief that a disease is curbed, while in reality it is progressing rapidly and sometimes carrying them on to certain death.

Many of the cure-alls contain alcoholic or narcotic ingredients. This accounts for the soothing effects that are often mistaken for cures. When a buyer is assured that some of the so-called remedies contain only vegetable substances, he should recall that cocaine, opium, strychnine, and many other poisonous drugs are derived from plants. Moreover, there are but few diseases in which a drug obtained from plants is known as a positive cure. Quinine is one of the few specifics. It cures malaria. It is claimed that no disease can be cured by the use of morphine, cocaine, chloroform, ether, acetanilid, or alcohol.

The Federal Food and Drugs Act. Although the Federal Food and Drugs Act, commonly known as the Pure Food Law, has been in force for more than a quarter of a century, its powers and limitations are still misunderstood. The act was designed to protect the public against harmful substances in commercially preserved foods and in medicinal compounds registered under a trade-mark. Under its provisions manufacturers are prohibited from making false statements on package labels regarding the purity, composition, or curative effects of their products. They are also required to state on the labels the presence and quantity of preservatives and of such drugs as morphine, heroin, cocaine, opium, acetanilid, and alcohol. They are not required, however, to declare the presence of such deadly poisons as arsenic, strychnine, and carbolic acid. Neither does the law prohibit misleading advertising. Everything considered, however, this act has been a tremendous force in promoting the scientific treatment of disease.

Drugs and patent medicines. We should not infer from the foregoing that all advertised remedies are harmful. To do so would be unjust to manufacturers and merchants. In fact, many patent medicines have excellent reputations. By patent medicines we mean those that are sold to the public under patented names. These names are registered by the government and become the property of the manufacturers. The

bottles containing the medicines bear labels according to the specifications of the Federal Food and Drugs Act by which we can tell what they contain. In view of this fact, it is up to us to use discretion in our purchases—that is, to discriminate between the good and the bad. The safest procedure is to buy only under the advice of a reputable physician. In this connection, the following facts should be kept in mind:

1. No medicine of a definite formula can cure all diseases even though it is beneficial in some cases.
2. No individual without a thorough medical training is capable of diagnosing disease.
3. No individual without such training has the knowledge necessary to regulate the dosage or treatment as the condition of a patient improves or grows worse. Many accidental deaths have resulted from the self-administration of medicines containing harmful drugs.

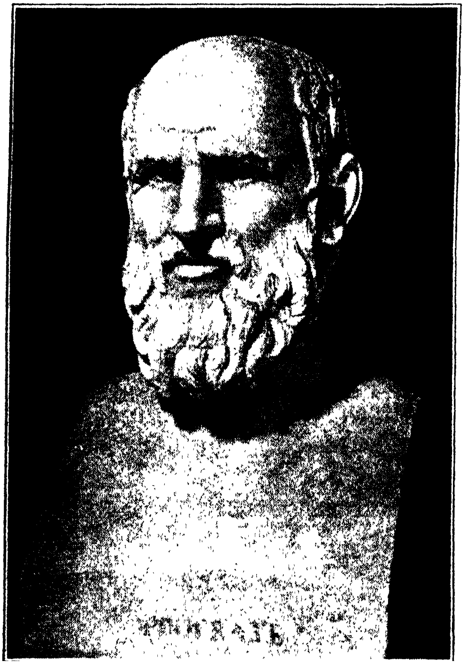
Problem 2. How have the science of medicine and the practice of surgery developed?

THE EARLY BEGINNINGS OF MEDICINE AND SURGERY

Hippocrates, the father of medicine. It was Hippocrates (hĭ-pŏk′rȧ-tēz), a Greek born about 460 B.C., who first turned to natural causes for an explanation of disease. Before his day all theories had been based on superstitious beliefs. The Greeks held the bodies of the dead in reverence; hence Hippocrates had no chance to rely upon dissections for information. He reasoned, however, that a person's body was in good health when four juices—blood, phlegm, yellow bile, and black bile—are present in correct proportions. In accordance with this theory he prescribed baths, a change of air, exercise, and proper diets in the treatment of disease. Although his explanation was rather hazy, it furnished a new basis for observations and directed attention to the facts of physiology. Thus the foundation was laid for the great field of medical science.

Hippocrates made another contribution worthy of note. He believed that every physician should take an oath to do the best he could for his patients. A doctor should never abuse his knowledge, lend poison to unsworn hands, or reveal professional secrets. Further, he must be temperate, honorable, humane, and clean, and must oppose fraud and superstition. To this day every person who is to become a physician must take an oath embodying all of these principles. This is remarkable considering the fact that Hippocrates lived nearly twenty-five hundred years ago!

THE FATHER OF MEDICINE
HIPPOCRATES

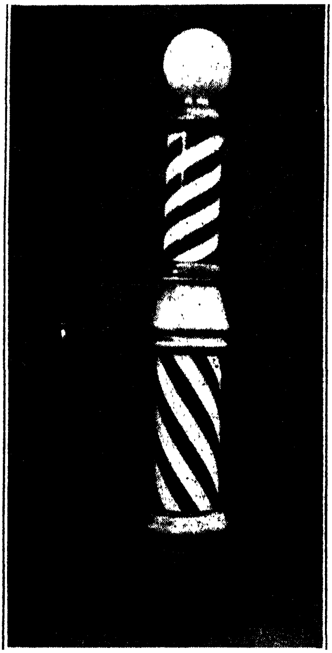


The ancient Greeks saw great value in a healthy body and a healthy mind. Hippocrates was a leader in the struggle for health which began about 400 B.C.

Galen, the founder of experimental physiology. Galen (gä′lĕn) (130–200 A.D.), after Hippocrates, was the most distinguished physician of ancient times. In carrying on his study of physiology he made a careful examination of the human skeleton and dissected the bodies of apes and many lower animals. He also made a detailed study of drugs and traveled widely for the purpose. Until the beginnings of modern medicine in the sixteenth century, Galen's medical works, especially those dealing with anatomy, dominated the field of medicine. Latin translations of his important works were studied in medical schools as late as the early nineteenth century.

Barbers as surgeons. From about 1000 A.D. to about 1500 A.D. surgery was considered a manual art to be practiced only by barbers. In fact, the red and white barber pole, which is still used today, was the emblem of their work. The red stripes represented blood, and the white stripes the bandages used for binding the wounds. Thus throughout the medieval period surgery was separated from medicine and practiced independently.

A REMINDER OF EARLY SURGERY



Ferdinand Hirsh

The barber pole of today was the emblem of early barber-surgeons who treated disease by blood letting.

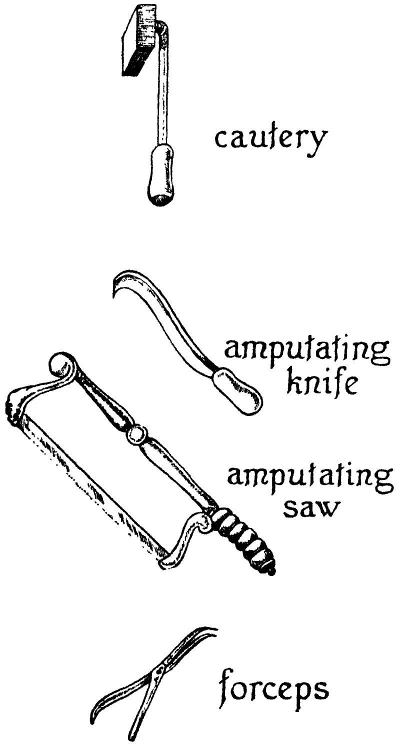
Two important events. For more than thirteen hundred years after the time of Galen little was done by observation and experimentation to study disease. In the sixteenth century, however, two events occurred which helped more than anything else to establish modern medicine and surgery. These events were (1) the invention of the printing press, which made possible the widespread dissemination of the medical knowledge of the Greeks; and (2) the founding of a school of art for the study of human anatomy. Standing out as notable leaders of the times were Andreas Vesalius (vē-sā′lĭ-ŭs) and William Harvey.

Vesalius, an ancient teacher of surgery. Prior to the time of Vesalius (1514–1565 A.D.), physicians would not handle patients with their own hands. Medical schools had been accustomed to call in barber-surgeons to make the actual dissections. It was Vesalius who put surgery upon a professional basis by teaching the proper methods of making dissections. Fortunately for the profession, he prepared several books on anatomy which he carefully illustrated with

drawings made from direct observations. Thus a genuine scientific method of procedure in surgery was begun.

William Harvey, discoverer of the circulation of the blood. By experimenting with the heart and blood vessels of lower animals and by placing bindings on the arms and legs of living persons, William Harvey (1578–1657) learned that blood flows in a circuit and is propelled by the heart. Until that time people had thought that the arteries were for the circulation of air.

PRIMITIVE SURGICAL INSTRUMENTS



How do these instruments compare with those used by physicians today?

In only one respect was Harvey's discovery incomplete. He did not learn just how blood reaches the veins. Four years after his death, however, a great Italian anatomist, Malpighi (mäl-pē′gē) (1628–1694), aided by the microscope, located the capillaries, and the discovery was complete.

Ambrose Paré, designer of surgical instruments. Modern surgery owes much to Ambrose Paré (på′rā′) (1517–1590). He put an end tc the use of red-hot searing irons, or cauteries, for stopping the flow of blood. In their stead he utilized ligatures, threads used for tying blood vessels, particularly the arteries. He also did much for the improvement of scalpels or surgical knives, saws, and other surgical apparatus. If we examine these instruments, however, we find that they were still very crude. For one thing,

they possessed fancy handles, which made excellent harbors for dangerous microbes. All in all, they were vastly different from the one-piece, all-metal instruments used today. Even so, Paré paved the way for present-day instruments and deserves great credit for his work.

Other early medical discoveries. During the sixteenth and the early seventeenth centuries a clinical thermometer and the stethoscope, an instrument for taking the rate of the heart beat, were invented. Then, too, the microscope, invented about the same time, gave a decided impetus to the study of body structures. Robert Boyle (1627–1691), an Irish chemist, laid the foundations for scientific chemistry. He helped free the subject from superstition and applied his findings to the use of drugs.

The story of the advancement of surgery would be incomplete without mention of *antiseptics* (ăn′tĭ-sĕp′tĭks) and *anesthetics* (ăn′ĕs-thĕt′ĭks), which have been developed largely during the last fifty years. Antiseptics are substances that arrest or destroy the growth of bacteria. Anesthetics are agents that produce insensibility to pain.

Problem 3. What are some of the more important modern scientific methods of treating disease and injury?

THE FIELD OF MEDICINE

The progress of modern medicine. The foregoing discoveries in the field of scientific medicine were very important, but even greater progress has been made within recent years. In earlier days physicians had a fair knowledge of anatomy, physiology, and pathology (the study of the diseased body), but they were unskilled in diagnosis. For the most part they had to rely upon general observation in reaching conclusions. They had few instruments to help them. In striking contrast, physicians today extend their observation by means of the microscope, the X-ray, the stethoscope, the fluoroscope, and hundreds of similar devices. They not only analyze fluids excreted by natural processes, but examine blood, spinal

fluid, and other substances which they extract from the body with various kinds of needles and tubes.

The thorough training provided in medical schools, and the subsequent experience in hospitals equipped with modern devices for the diagnosis and treatment of disease, give the medical expert of today a preparation excelled in few other lines of endeavor. Along with the advance in the practice of medicine has gone a corresponding progress in hygiene and sanitation. Under these improved conditions, life expectancy, within the last century, has increased from thirty-five years to over sixty years.

The physician as a guardian of health. We should look upon the physician or "family doctor" as our friend. His thorough knowledge of our individual and family history makes him the logical person to consult for the prevention and cure of disease. Occasionally, because of the peculiar nature or seriousness of a disease, it may be advisable to consult a specialist. A specialist is a physician who devotes his entire attention to a limited field, as the respiratory tract or the digestive tract, or even to one particular organ, as the heart or the eye. Thus, at the present time, we have at our command the services of men who prescribe for only a part of the body. The thorough training of all physicians and their high ethical standards insure the right kind of health service whenever it is needed.

THE FIELD OF SURGERY

The wonders of modern surgery. The discovery of anesthesia (ăn′ĕs-thē′sĭ-ȧ) and the development of antisepsis (ăn′tĭ-sĕp′sĭs) have added greatly to the success of modern surgery. The tracing of germs of infections to their sources has greatly modified surgical practices. As a result, surgical instruments are now sterilized, rubber gloves are worn, and the danger of infection has nearly disappeared.

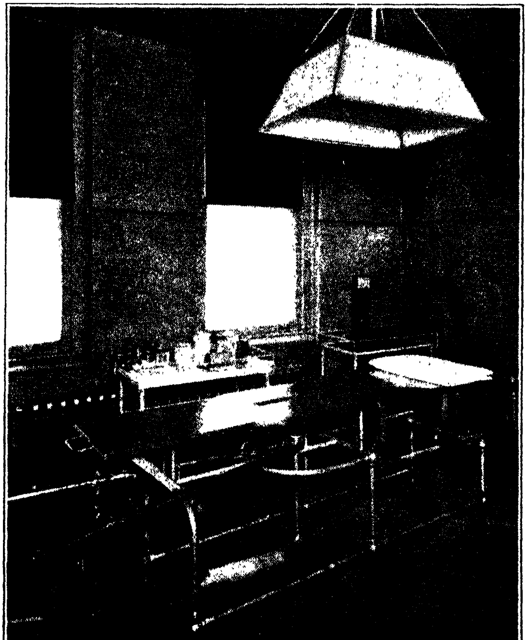
Experience and knowledge have given the surgeon of today such ability and skill that he accomplishes remarkable results. He works safely on either the outside or the inside of the body. He operates upon the chest and abdomen, often preventing

death by removal of a tumor, cancer, abscess, or some diseased organ, such as a kidney or the appendix. Occasionally the crippled are made to walk, the blind to see, and the deaf to hear. Recently successful operations have even been performed on such delicate and sensitive organs as the brain.

HOSPITALS AND CLINICS

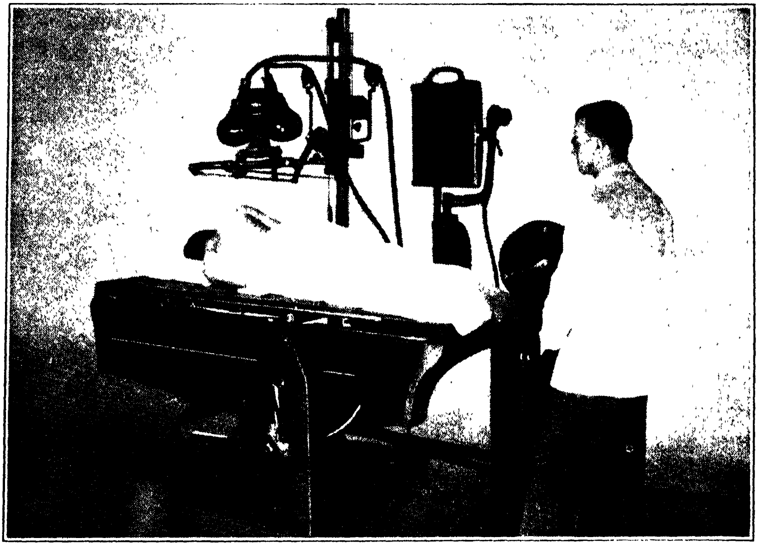
Homes for the sick — hospitals. Not only for their service in helping the sick, but for their value in protecting the well, hospitals may be considered essential to modern life. In the average home, conditions are often such that a patient cannot receive the proper and constant care necessary for recovery. In hospitals the services of the physician and trained nurse are available at all times. The diet, which is very important during convalescence as well as when the illness is most pronounced, is constantly watched. The patient is not unduly pampered, nor is his every wish granted, as so often happens when home care is undertaken. In order to appreciate the many advantages of a hospital, we should make a tour of inspection if

A MODERN OPERATING ROOM



In this operating room every precaution is taken to insure cleanliness, efficiency, and consequently life itself. Above the operating table is a shadowless electric light which enables the surgeon to see clearly what he is doing.

AN EXAMPLE OF MODERN DIAGNOSIS



Century Photos

The X-ray machine is one of the most important instruments in the diagnosis of disease. Through its use it is possible to examine parts of the body that could never be observed before.

it can be arranged. Such a tour will convince us that the treatment of disease is indeed a scientific procedure.

Institutions for diagnosis — clinics. Clinics are institutions for the diagnosis and treatment of disease. Some give attention to diseases of all kinds, while others work in limited fields. A recent investigation in the United States reveals that more than ten million visits were made to free clinics in a single year. This clearly shows that people are becoming conscious of the fact that scientific treatment of disease is indispensable to the conservation of health. Many diseases formerly ignored until patients were confined to their beds are now diagnosed in their early stages so that permanent cures may be effected. In 1900 there were only one hundred fifty free clinics in the United States; today there are more than five thousand. Thus the public is being convinced that health is best cared for by the scientifically trained.

THE CONSERVATION OF PUBLIC HEALTH

Public health—public wealth. The work of local and state boards of health, of the United States Public Health Service, and of such agencies as the International Health Board is invaluable in the prevention or eradication of disease. Such matters as the enforcement of health laws, the establishment of quarantine, the condemnation of sanitary menaces and nuisances, the keeping of records and vital statistics, the collection of materials for the education of the public, and similar procedures can be handled successfully only by public boards of health and officials authorized by law. Their efforts to prevent disease constitute a form of health insurance which guarantees: (1) the saving of life; (2) the lengthening of life; (3) the avoidance of much pain and misery; (4) the reduction of time lost by wage-earners; (5) the making of a cleaner, better, happier, and more beautiful world in which to live.

SUGGESTED ACTIVITIES

I. Self-Organization Summary

A. Primitive Methods of Treating Disease
1. How did primitive peoples explain disease?
2. What methods did they use for treatment?

B. The Rise of Cure-Alls
1. Why did many people in former years rely on cure-all remedies?
2. What is meant by the statement that a specific disease requires a specific remedy?
3. How has the Federal Food and Drugs Act aided in the scientific treatment of disease?
4. How may you wisely select patent medicines and drugs?

C. The Rise of Medicine and Surgery
1. How did each of the following contribute to the early development of medicine and surgery: (*a*) Hippocrates; (*b*) Galen; (*c*) Vesalius; (*d*) Harvey; (*e*) Boyle; (*f*) Paré?
2. Mention some of the most important steps in the development of scientific medicine and surgery.

D. Present-Day Agencies
   1. Describe some of the wonders of modern surgery.
   2. How does a hospital differ from a clinic?
   3. What five social benefits are derived from public health agencies?

II. Display Posters and Collections

A. Prepare cardboard posters showing
   1. Lists of home remedies
   2. Health-protective agencies of your community
   3. Sketches of early surgical and medical instruments
   4. Pictures of modern surgical and medical instruments

III. Field Trips

A. To a hospital for the purpose of studying modern apparatus and the latest methods of treating disease and injury

B. To a modern factory for the purpose of noting devices for the safety of workers; the provisions for insuring fresh air and sunshine; sanitary toilet facilities; first-aid stations; and other means of promoting health

IV. Special Reports

A. Barber-surgeons
B. Witchcraft
C. Voodoo doctors and medicine men
D. Modern superstitions concerning disease
E. Psychoanalysis
F. The traffic in narcotics
G. The Harrison Narcotic Law
H. Health services in the community

REFERENCES[1]

1. Fishbein, Morris. *The New Medical Follies.*
   a. An encyclopedia of cults and quackeries, pp. 13–64
   b. The physician of the future, pp. 214–235
   c. Psychoanalysis, pp. 181–204
2. Haggard, Howard W. *Mystery, Magic, and Medicine.*
3. Hoffman, Dr. Richard H. *The Struggle for Health.*
   a. History of surgery, pp. 246–281
   b. Development of anesthetics, pp. 234–245

[1] The pages listed here are those found in the editions indicated in the alphabetical list of references given at the end of this book.

4. Kovacs, Richard. *Nature, M. D.*
   Presents modern methods for the treatment of disease
5. Williams, Henry S. *Drugs against Men.*
   a. Alcohol the great handicapper, pp. 19–76
   b. In thrall to the poppy, pp. 135–147
   c. Between devil and deep sea, pp. 149–154
6. *Book of Popular Science, The.*
   a. Drugs — their uses and abuses, Vol. 6, pp. 2095–2104
   b. The long past and the great future of medicine, Vol. 13, pp. 4509–4518
7. *Compton's Pictured Encyclopedia.*
   a. Anesthetics, Vol. 1, pp. 196–197
   b. Magic rites to cure illness, Vol. 9, pp. 30–33
8. *New Wonder World, The.*
   a. The X-ray and its use, Vol. 2, pp. 147–150
   b. The march of science, Vol. 1, pp. 259–274
9. *World Book Encyclopedia, The.*
   a. Medicine and drugs — outlines, Reading and Study Guide, pp. 8408–8418
   b. Medical schools — a doctor's qualifications, pp. 4372–4373

VISUAL AIDS

Films (16 mm.)

A. Herman A. DeVry, Inc., 1111 Center Street, Chicago, Illinois.
   1. Doctor. 1 reel, silent, $24.00.
      Shows the training necessary to qualify; medical schools, clinics, hospitals, and an actual operation; nursing as a profession

B. General Electric Company, Schenectady, New York.
   1. Revelations by X-ray. 1 reel, silent, free.

C. Indiana University, Extension Division, Bloomington, Indiana.
   1. Home Nursing: Routine Procedures. No. KK–19. 16 mm. $1.00 per day.
   2. First Aid: Carrying Injured and Care of Minor Wounds. No. KK–25. 16 mm. $1.00 per day.
   3. Working with Civic Organizations. No. H–6. 16 mm. $1.00 per day.
      Encourages civic pride

UNIT FIVE

FRIENDS AND FOES AMONG THE INSECTS

SUGGESTIONS TO THE TEACHER

In many schools students will already have learned much about insects through the study of elementary science. In other schools elementary science may not have been offered and students will have acquired little scientific information. The purpose of this unit is twofold: (1) to stimulate those who have already studied insects so that they will want to organize their information; and (2) to arouse those who have not studied insects so that they will approach the subject with curiosity and interest. Surely the importance of the study cannot be overemphasized, since insects are more numerous than all the other animals taken together and since they cause an estimated loss of approximately $2,265,000,000 each year. This unit, then, may be considered a brief introduction to the study of insects from both the scientific and the economic points of view.[1]

OBJECTIVES

I. Facts and principles

- A. To learn the names, the distinguishing physical characters, and the habits of ten or more harmful insects and ten or more helpful ones
- B. To develop an understanding of some of the scientific methods of controlling both helpful and harmful insects
- C. To learn about the principle of "the balance of nature"

II. Attitudes

- A. To appreciate the economic importance of scientific control of insect life
- B. To appreciate the need for coöperating with the proper authorities in the control of insect life
- C. To appreciate the wide variety of insects by collecting and mounting twenty insects so selected as to illustrate most of the orders. Each insect should be studied from the standpoint of identification and life habits.

[1]Not all of the material on insects is presented in this unit. The relation of insects to disease is treated in Unit Three. The story of the behavior of certain insects, such as ants, bees, and termites, will be found in Unit Ten

UNIT FIVE

FRIENDS AND FOES AMONG THE INSECTS

AN INSECT THROUGH A MICROSCOPE

Just as the butterfly looms larger to the young man looking through the glass, so may your interest in the study of insects increase as you pursue the work of this unit.

VISITING WITH THE DOODLE BUG

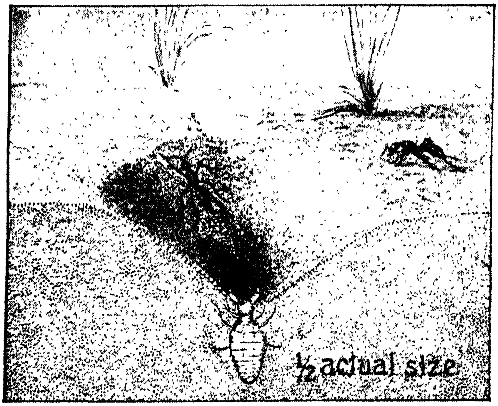
PREVIEW

Of all forms of life few are more interesting than insects. We see them all about us and perhaps have noted their many sizes, shapes, and colors. They live in interesting places and carry on interesting activities. Some of their activities show organized effort and indicate very careful planning. Let us consider, for instance, the activities of the ant lion or doodle bug. This insect resembles a hermit and lives a life of seclusion. It lives only in sandy places where there is almost complete absence of life. Therefore we find it either in small

sandy areas near lakes and streams or on the broad expanses of a desert. How it ekes out an existence makes a very interesting story, for there seems to be almost nothing for it to eat.

In view of the absence of life around it, we should scarcely expect the ant lion to get food by setting a trap, but that is just what it does. It digs an inverted conelike hole in the sand and waits patiently at the bottom for its victim. When the victim comes, the ant lion puts up a strong fight as it makes its attack. For weapons, it uses its three pairs of jointed legs, particularly its hind legs, which are long and peculiarly twisted. It also uses its sharply pointed and tong-shaped jaws to a very good advantage in a fight to overcome its prey.

THE HOME OR TRAP OF THE ANT LION



Woe be unto the ant or other unsuspecting insect that wanders accidentally into this trap. (Cross-sectional view)

The ant lion may go without food for days and even weeks while it waits at the bottom of its trap for its prey. Finally an ant, absorbed in its work and hurrying along, accidentally falls into the opening of the trap. Should the ant try to crawl out, the ant lion undermines the sand in its path, causing a landslide from which it cannot escape. Then, too, if necessary, it uses its flat head as a shovel to hurl sand particles like projectiles from the bottom of the pit. It is amazing to see the size of the sand grains which the ant lion can hurl through the air. Some of these particles hit the ant and knock it back into the trap. The ant lion quickly pierces the body of the ant with its jaws and sucks the blood of its victim. So it is that the ant lion survives the famine of the waste places.

Learning how the ant lion survives should help you to appreciate the struggle for existence among lowly creatures. The following problems are presented with the hope that they will make you wish to learn more about insects and that they will enable you to think of insects as both friends and foes.

PROBLEMS

1. **How do the forms of insects and their parts give a clue to some of their habits?**
2. **How are insects collected, preserved, and named?**
3. **Why are insects of economic importance?**
4. **How can insect pests be controlled?**

Problem 1. How do the forms of insects and their parts give a clue to some of their habits?

Insects are of special interest because (1) their structure and habits are unusual, (2) they are easy to collect and keep under observation, and (3) they are unlike larger animals in the parts of their bodies used for seeing, hearing, smelling, and tasting.

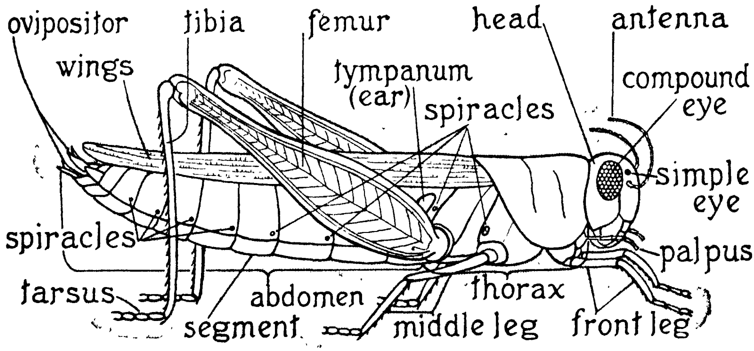
What is an insect? Everyone is familiar with such creatures as grasshoppers, butterflies, bees, flies, and mosquitoes, which are called *insects*. They differ from the higher animals in having their skeletons on the outside of their bodies instead of on the inside. Such an outside skeleton is called an *exoskeleton* and is used largely for protection. It consists of the outer membrane of the body wall, in which there is a deposit of horny material called *chitin* (kī′tĭn).

THE PARTS OF AN INSECT

The body of an insect is divided into three principal parts: the *head*, *thorax* (thō′răks), and *abdomen*. The head is made up of a single segment which includes the eyes, antennae, and mouth parts. The thorax is divided into three segments to which are attached six legs and usually four wings. The number of legs is important in distinguishing insects from other

closely related animals. The number of segments in the abdomen varies with the kind of insect.

THE MAKE-UP OF A GRASSHOPPER



The grasshopper is typical of all winged insects in its make-up.

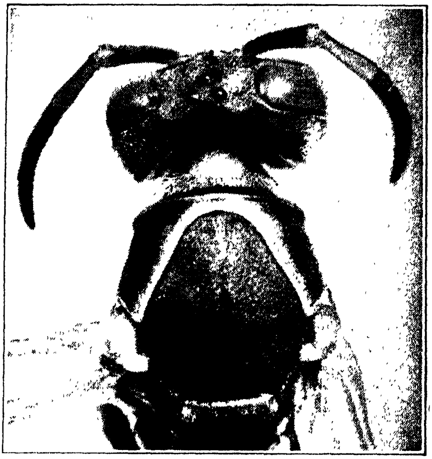
DEPENDENCE OF THE INSECT UPON ITS HEAD

When we examine the heads of insects and note the absence of ears and nose, we may wonder whether they can hear and smell. Upon observation we shall find, however, that they seem to have about the same senses as most other animals. The difference is in their sense organs rather than in their senses. Let us now see what some of these organs are.

If we had a thousand eyes! Sometimes we wish we had eyes in the back of our heads. If we were equipped like insects, we should almost have our wish, for insects can see in several directions at once. They do this through two large compound eyes and three simple ones. Each compound eye is made up of many tiny six-sided surfaces or *facets* (făs′ĕts) that give it the appearance of a honeycomb. A facet is really the lens of a separate eye called an *ommatidium* (ŏm′ȧ-tĭd′ĭ-ŭm). Each compound eye may include from fifty to as many as a thousand or more ommatidia.

The facets are probably adapted to receiving the stimuli of light, color, and motion. Each ommatidium seems to be capable of forming an image of only a part of what comes within the range of vision. Hence several of the ommatidia must

THE EYES OF A WASP



Hugh Spencer

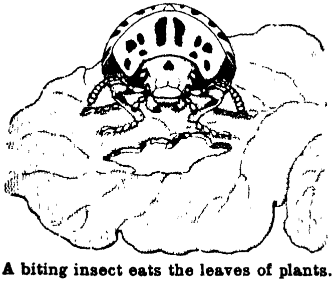
Like other insects, the wasp has a total of five eyes. The three small eyes in the center are simple eyes. The two larger kidney-shaped eyes at the sides are compound eyes through which the insect sees in several directions. (Greatly magnified)

function together to enable the insect to see. Even though an insect is well equipped with ommatidia, its sense of sight is believed to be poorly developed.

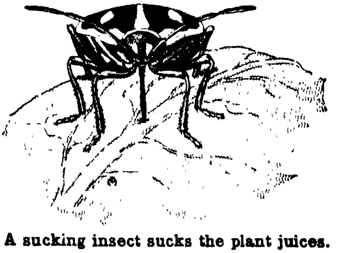
The three simple eyes of an insect are called *ocelli* (ŏ-sĕl'ī). They are arranged in the form of a triangle in the front of the head, and probably have little use except to help the insect distinguish between light and darkness.

What insects do with their mouths. It is necessary to learn about the mouth parts of insects before we can consider how they obtain and take in their food. In general, because of the nature of their mouth parts, insects may be classified into two large groups.

TWO TYPES OF INSECT MOUTHS



A biting insect eats the leaves of plants.

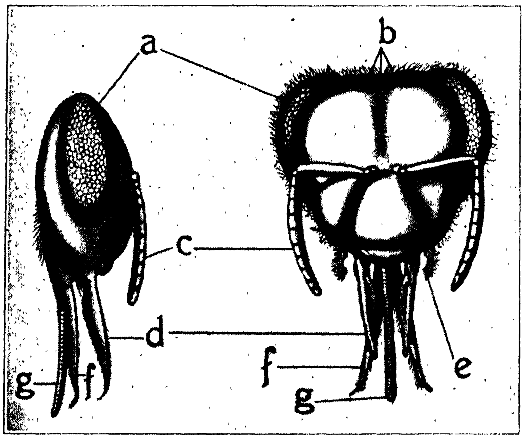


A sucking insect sucks the plant juices.

The members of one group, such as the grasshopper, have mouth parts for biting or chewing their food. The members of the other group on the contrary, such as the butterfly, have mouth parts for sucking their food.

The mouth parts of a biting or chewing insect consist of an upper lip or *labrum* (lā′brŭm), a lower lip or *labium* (lā′bĭ-ŭm), and two pairs of jaws. The upper jaws, called *mandibles* (măn′dĭ-b'lz), are toothed on the edges facing each other. The lower jaws, or *maxillae* (măk-sĭl′ē), contain feelers called *palpi* (păl′pī). Both the upper and the lower jaws move sidewise instead of up and down. The mandibles are probably most used for cutting and chewing leaves, while the palpi and other parts of the lower jaws hold the leaf in place, and aid in getting the food into the mouth.

THE PARTS OF A BEE'S HEAD



Courtesy *World Book Encyclopedia*

The drawing at the left shows a side view, that at the right, a front view of the bee's head. The parts are:

(a) Compound eye
(b) Three simple eyes (ocelli)
(c) Antennae
(d) Maxilla
(e) Mandible
(f) Labial palpi
(g) Tongue (ligula) or sucking tube

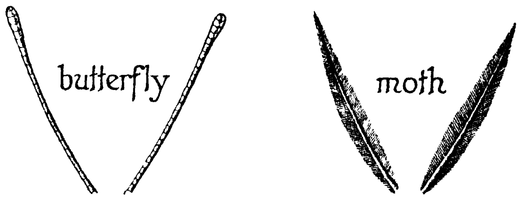
Most insects which feed upon the nectar of flowers or other liquid food, such as the butterfly and moth, have their mouth parts adapted to sucking. Some, such as the butterfly, have a long sucking tube called a *proboscis* (prŏ-bŏs′ĭs). Others, such as the bee, have modified sucking parts. Those of the first group often keep their long *proboscides* (prŏ-bŏs′ĭ-dēz) coiled up under their heads. When in search of food, however, they alight upon an open flower, uncoil their proboscides, and thrust them deep into the nectar cup at the base.

Does the grasshopper chew tobacco? This is a question commonly asked by people who have had a grasshopper spit upon them as if not caring for friendly advances. The brown, ill-smelling liquid that the grasshopper exudes when captured

is the partially digested plant food upon which it lives. The grasshopper is a hardy insect and eats many types of vegetation. At times great swarms cross certain regions and kill all plant life, leaving the land entirely barren.

How an insect experiences sensation. The principal organs of an insect for experiencing the sensations of touch and smell are the *antennae* (ăn-tĕn′ē). These organs are jointed appendages which occur in pairs and are attached to the head either between or in front of the eyes. They vary in form in different species of insects. Those of the butterfly have the form of a thread with a knoblike swelling at the tip, whereas those of the moth have a feather-like form. Insects doubtless use their antennae as organs of touch and smell and thereby keep themselves informed as to the nature of their surroundings. Some scientists believe that antennae also serve as organs of hearing. Perhaps they function somewhat like an aerial of a radio by picking up sensations from their environment. Sensations of taste are received mostly through the palpi that are located on the lower jaw.

THE ANTENNAE OF MOTHS AND BUTTERFLIES



The antennae of butterflies are long, jointed, and thickened at the end, while those of moths are feathery.

Recent investigations indicate that the sensations of touch, taste, hearing, and smell may be partially received through certain *chitinous* (kī′tĭ-nŭs) *hairs* that are scattered over the entire surface of an insect. These hairs are most abundant on the movable parts of the body and especially about the mouth. Some are found in pits or canals on the body.

WHERE THE WINGS AND LEGS ARE ANCHORED
THE THORAX

The middle region of an insect's body is called the *thorax*. It consists of three firmly jointed rings or segments to which the legs and wings are attached. The segment nearest the head

is called the *prothorax* (prȯ-thō'răks), the middle one the *mesothorax* (mĕs'ȯ-thō'răks), and the hind one the *metathorax* (mĕt'ȧ-thō'răks).

A pair of legs is attached to the lower part of each of these segments. When two pairs of wings are present, one pair, called the *front wings,* is attached to the upper part of the mesothorax; the other pair, called the *hind wings,* is attached to the upper part of the metathorax.

A typical insect leg, as shown in the drawing of the grasshopper on page 168, is made up of several parts. Nearest the thorax are two small segments. Next is a long thick part called the *femur* (fē'mŭr), and farther out is a long thin part called the *tibia* (tĭb'ĭ-ȧ). At the extreme end of the leg is the *tarsus* (tär'sŭs), or foot, which is made up of three segments in the grasshopper but varies from one to six segments in other insects. The last segment of the foot of the grasshopper has two claws, between which there is a toe pad. The very strong hind legs of the grasshopper account for its being able to jump such great distances and consequently to escape its enemies.

The form and texture of wings vary in different kinds of insects. The wings of most insects are membranous, but have veins or nerves which are somewhat thicker than the surrounding structure. The grasshopper has a pair of long leathery front wings and, underneath these, a pair of delicate hind wings. When the insect is at rest, the hind wings remain folded, like a closed fan, but open up when it is in flight. The beetle has a pair of hard shell-like front wings which meet in a straight line down the middle of its back and extend the full length of its body. Its hind wings, like those of the grasshopper, are delicate and folded beneath its front wings.

The wings of moths and butterflies have unusual color patterns and differ from those of all other insects in being covered with tiny overlapping scales. When we handle butterflies, these scales come off as a fine powder.

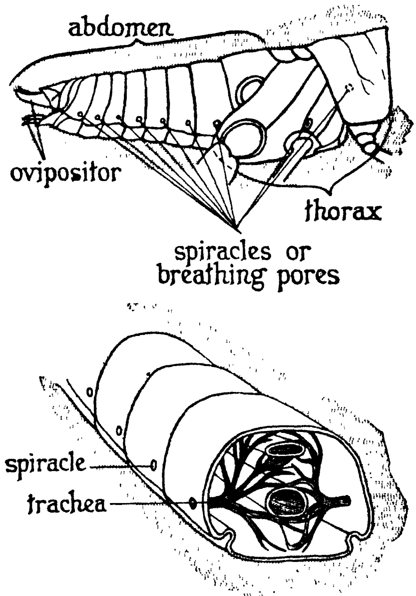
The dragon fly rests with its long wings extended horizontally from its body. What attracts attention in these wings is their delicate texture, fine network of veins, and color patterns.

THE ABDOMEN OF INSECTS ESPECIALLY USEFUL

If we watch an insect closely, we shall see that its abdomen expands and contracts regularly. This is possible because the abdomen is made up of segments so arranged that they can work like a bellows. It is in this way that the insect breathes.

On each side of the segments of the abdomen and thorax are small openings called *spiracles* (spĭr′ȧ-k'lz), which open into a branching system of air tubes called *tracheae* (trā′kė-ē). The spiracles admit the air and the tracheae conduct it to every part of the body. Thus the insect does not breathe through a nose as human beings and other higher animals do, but through spiracles in its abdomen and thorax. The bellows-like expansion and contraction of the abdomen permits the taking in and giving out of air as it breathes.

THE BREATHING ORGANS OF INSECTS



Insects have no organs corresponding to the lungs of human beings. Air passes into an insect's body through the spiracles (breathing pores) and is distributed by pipelike air tubes called tracheae.

The hearing organs of insects. Another peculiar characteristic of insects is the location and nature of their hearing organs. We have already learned that they do not have ears on their heads as larger animals do. In the grasshopper the hearing organs are hidden under the wings, one on each side of the first abdominal segment. Each organ is merely a large disklike opening covered by a very delicate membrane called the *tympanum* (tĭm′pȧ-nŭm). The katydid has its hearing organs near the base of the tibia of its forelegs.

The egg placer. The posterior end of the abdomen of a female insect consists of an organ called an *ovipositor* (ō′vĭ-pŏz′-ĭ-tẽr). In the grasshopper this is made up of two pairs of hard, curved, sharp-pointed parts which are used for boring a hole in the soil in which to lay eggs.

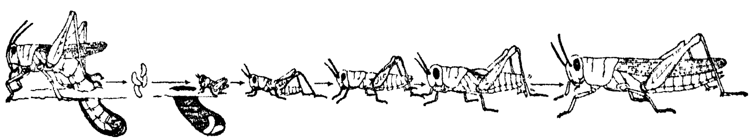
NATURE'S ODD WAY OF CHANGING AN INSECT FROM AN EGG TO AN ADULT

Nearly all insects go through changes in form during their development from an egg to an adult. The process embodying all these changes is called *metamorphosis* (mĕt′ȧ-môr′fō-sĭs).

From Tiny Nymph to Adult Grasshopper

If we watch grasshoppers in the fall, we shall see the female grasshopper dig a hole in the ground with her ovipositor and there lay an oval mass of twenty to thirty eggs. In spring a tiny wingless creature, or *nymph,* which looks much like an adult grasshopper except for its very large head and a strange

FROM EGG TO ADULT GRASSHOPPER



From eggs laid in the ground tiny nymphs (young grasshoppers) hatch. By successive molts, as shown in the illustration, the adult stage is reached.

little body, hatches from an egg. As the young nymph grows, it develops a new skin, bursts its firm outer covering, or exoskeleton, and crawls out of it. This shedding of the old skin is called *molting.* The nymph molts several times before reaching the adult stage. Wings appear first as tiny projections and increase in size with each molt until the adult stage is reached. The body of the nymph more nearly resembles that of an adult grasshopper after each molt.

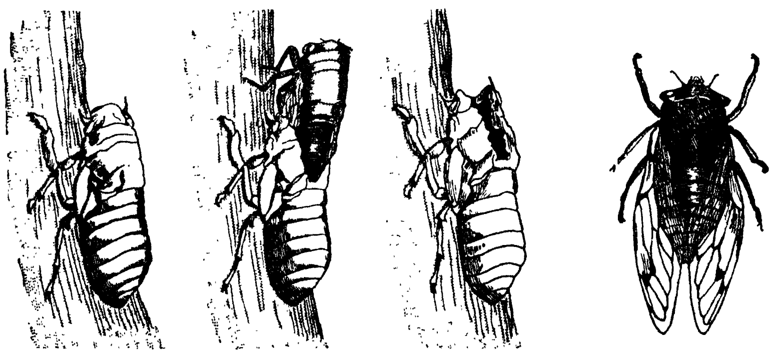
The grasshopper belongs to a group of insects which undergo *incomplete metamorphosis.* By this we mean that the young insect somewhat resembles the adult in form as soon as it leaves

the egg, but that it continues to undergo certain changes until it becomes an adult. Other commonly known insects that undergo incomplete metamorphosis are squash bugs, plant lice, scale insects, and cicadas (sĭ-kā′dȧz).

A Life Cycle Seventeen Years in Length

The cicada. One of the most interesting stories of incomplete metamorphosis of insects is the story of the seventeen-year cicada.[1] The female cicada lays her eggs in a cavity made by slitting the twigs or small fruits of trees with her sawlike ovipositor. Tiny nymphs hatch in five to eight weeks. These nymphs bury themselves in the ground, where they remain seventeen years.[2] During this time they live by sucking juices from the roots of forest and fruit trees. They then crawl out of the ground and up the trunks of trees, where they complete their last molt. Their skins burst open and they appear as adult cicadas, with broad heads and bodies and large clear wings.

THE CICADA CHANGING ITS "SUIT"



On the left is a nymph, next is a cicada emerging from its shell, and next is the empty shell after it has left. On the right is the newborn cicada drying its wings.

A common species of cicadas is the dog-day harvest fly. This cicada requires two years for its metamorphosis. The adult is black and green in color and is a great singer. Its song may be recognized by volume and high shrill notes.

[1] The cicada is wrongly called a locust. It does not even belong to the same order as locusts. Grasshoppers are locusts.

[2] Thirteen years in the South.

"Beware of the digger wasp," says the cicada. Although the cicadas sing merrily throughout the day, we must not conclude that they are free from danger and suffering. Certain other insects, such as the digger wasp, hornet, and dragon fly, prey upon them. The digger wasp is sometimes called the mining digger wasp because it bores two or three feet into the ground to build its home. Here it stores a food supply in the form of helpless cicadas, which it usually captures from the sides of trees after paralyzing them with its sting. Is it not remarkable that the digger wasp stings a cicada in such a way as to produce paralysis and thus insure itself of living food rather than dead? After capturing a cicada, the digger wasp glides through the air with its victim to its home in the soil. Then it lays eggs in the cicada's body and uses it as a nursery for the young when they hatch. Thus the living body of the cicada furnishes warmth and food for developing wasps.

A DIGGER WASP AND ITS PREY

Courtesy *Nature Magazine*

This wasp is carrying a cicada that it has paralyzed with its sting.

In a similar manner another type of digger wasp captures caterpillars. It drags the caterpillars into a tunnel, deposits eggs in their bodies, and closes the tunnel. Thus it provides a supply of food for its young.

Changing from an Ugly "Worm" to a Beautiful Butterfly

Nature uses a long and unusual process in bringing some insects to the "grown-up" stage. Strange changes take place between the egg and adult stages. The metamorphosis of insects is one of the greatest mysteries of nature. Just how an ugly "worm" finally emerges as a beautiful butterfly with a varied color design holds some of our greatest scientists spell-

bound in their efforts to fathom the mysteries of life. Who, for instance, can explain in full detail the miracle of how the gorgeous tiger swallowtail butterfly comes into existence? Let us study this insect to see just what happens as it develops.

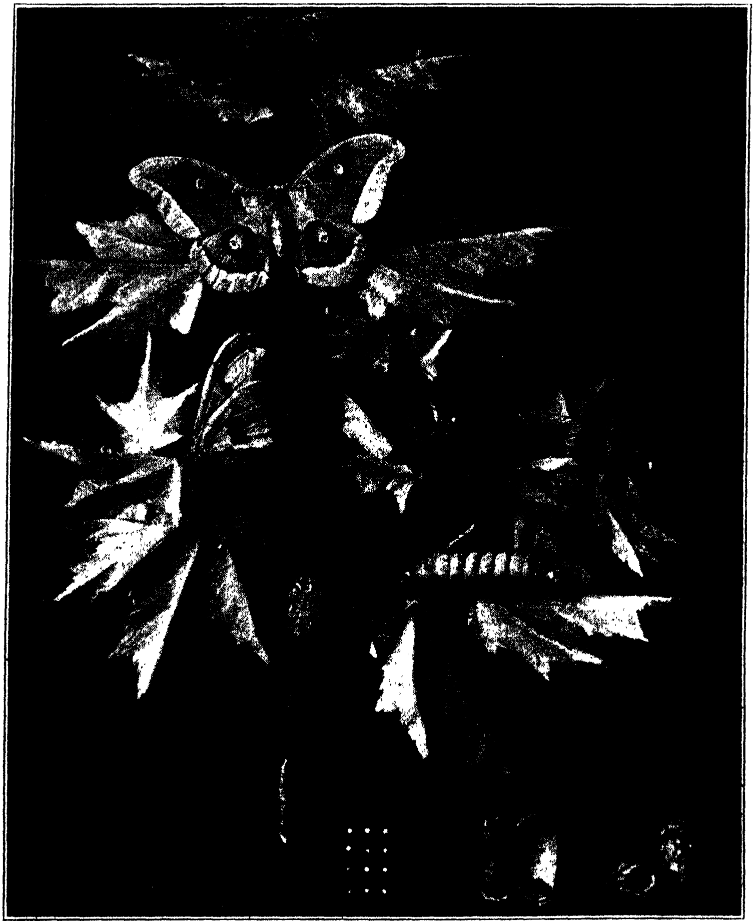
How the tiger swallowtail butterfly comes into being. This butterfly lays its eggs in early summer on the leaves of fruit trees and certain other plants. In about ten days a tiny worm-like animal called a *caterpillar* hatches from each egg. The caterpillar belongs to the *larva* stage in the life of a butterfly.

The young caterpillar feeds upon the leaves of the tree where it has hatched. When it is not feeding, it enjoys life by spinning silken threads into a soft bed upon which to rest. It molts as it grows. When full grown it has a beautiful dark green color, decorated with large yellow eyespots on the third segment of its thorax, and a yellow band around the back part of its first abdominal segment. It is protected from its enemies by fleshy horns or scent organs which shoot out from the upper part of the prothorax when it is attacked. The effectiveness of the scent organs comes from the strong odors which they give off when enemies approach.

The caterpillar is a walking animal and has several feet. That of the tiger swallowtail butterfly has three pairs of *true legs* on the thorax, four pairs of fleshy thickenings on its abdominal segments called *prolegs* (prō′lĕgz′), and a hind *prop-leg* at the end of its abdomen.

When the caterpillar completes its growth, it crawls to a sheltered spot and attaches itself by means of a silken loop to a firm support, such as a limb. From all outside appearances, it then goes into a resting period or *pupa* (pū′pȧ) stage and is called a *chrysalis* (krĭs′ȧ-lĭs) or pupa. To the casual observer the pupa, because it has no head, feet, or wings, appears to be inactive. Inside, however, a great mystery is taking place. If we examine the pupa very carefully just before it is ready to burst open, we can see legs, wings, and antennae forming just beneath the skin or shell. Finally the shell breaks and an adult butterfly emerges. Soon it straightens its crumpled wings and flits away in the sunlight.

THE LIFE HISTORY OF THE POLYPHEMUS MOTH

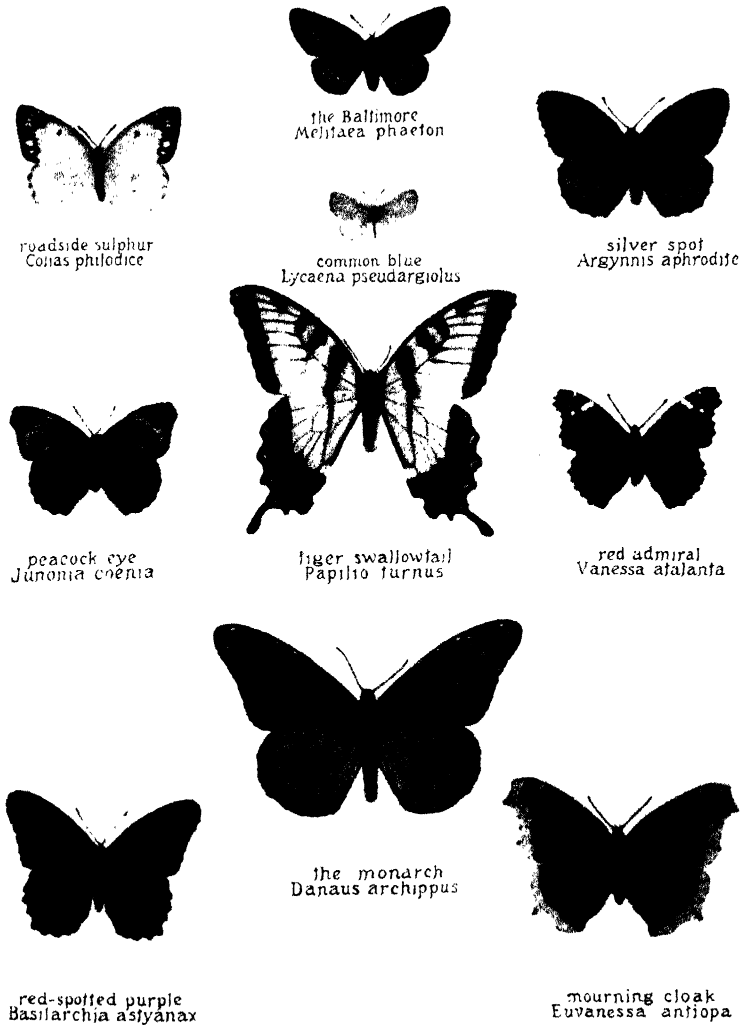


Courtesy Field Museum of Natural History

A large, bright green caterpillar emerges from an egg, as shown in the picture at the right among the leaves. From this wormlike stage the creature goes into the chrysalis or pupa stage, as shown at the center near the bottom. Finally a beautiful yellow-brown moth emerges from the shell, as shown at the top and left. From left to right at the lower right in the picture are several eggs, an open pupa, and two pupa shells.

The meaning of complete metamorphosis. An insect like the butterfly or moth, which does not resemble the adult when it leaves the egg, but which changes completely before reaching

COMMON AMERICAN BUTTERFLIES

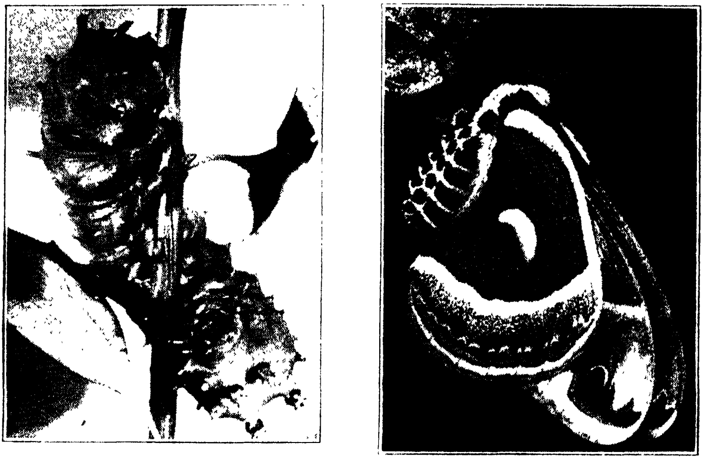


Courtesy General Biological Supply House

the adult stage, is said to undergo a *complete metamorphosis.* This means that it passes through four separate stages, the egg, larva, pupa, and adult, before its life cycle is complete.

Other insects that undergo complete metamorphosis are flies, mosquitoes, beetles, and moths. All of these insects

COMPLETE METAMORPHOSIS IN THE CECROPIA MOTH



Lynwood M. Chace

One of the most beautifully marked moths is the Cecropia. From the cocoon spun by the hideous caterpillar on the left, there emerges the lovely creature shown on the right.

differ greatly in their structure, habits, habitats, and the food they eat in the various stages of their metamorphosis. For example, the larva of a fly, which is called a *maggot* (măg'ŏt), lives in decaying garbage or in a manure pile, whereas the fly itself is at home in a variety of places. Both the larva and the pupa of the mosquito are active and are adapted in their structure to a water environment in stagnant ponds.

Problem 2. How are insects collected, preserved, and named?

Almost every kind of insect has certain peculiarities that make it as interesting as the doodle bug, the tiger swallowtail, or the seventeen-year cicada. If we have enjoyed studying these insects, we shall doubtless want to search for further

information about others. Then, too, after a little study, we shall surely want to go into the field and make an insect collection. A few suggestions for this work follow.

HOW TO MAKE AN INSECT COLLECTION

In making a collection it is wise to confine your efforts to a search for one kind of insect rather than several kinds. A few of the more common and most interesting insects are:

1. Butterflies
2. Moths
3. Beetles
4. Dragon flies
5. Grasshoppers or related types, as crickets and katydids
6. Bugs, such as the squash bug, cicada, and stinkbug

A BREEDING CAGE FOR INSECTS

Courtesy *New Wonder World*

In a cage of this type you may observe the activities of insects you collect. Learn to know the vegetation that your insects prefer and feed them accordingly.

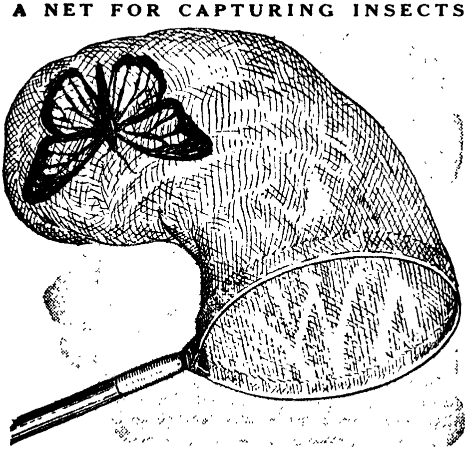
Materials needed for the insect hobby. Fortunately the materials needed for collecting insects may be secured at little cost, or may be partly assembled from materials at hand. The following are usually considered necessary:

1. Specimen containers:
   - *a.* Fish bowls for living specimens. Glass jars and large bottles may be used instead.
   - *b.* Screened boxlike cages like the above for living specimens.
   - *c.* Vials in which to bottle small insets. When collections are made to show life history, the egg, larva, pupa, and adult stages should be put into separate vials.
   - *d.* Pill boxes in which to preserve life histories.

e. Specimen boxes for preserving dried insects. Cigar boxes or any other flat boxes made of wood may be substituted, or cardboard boxes may be used.

2. Chemicals for preserving collections:
   a. Alcohol or formaldehyde solutions.
   b. Naphthalene crystals (moth balls). These crystals are necessary in order to keep living insect pests from attacking collections preserved in specimen boxes.
3. Killing preparations:
   a. Carbon tetrachloride or a nonexplosive cleaning fluid.
   b. A cyanide bottle.
   c. Other chemicals, such as chloroform, ether, and gasoline, may be used, but they are not recommended.
4. Mounting materials:
   a. Insect pins. Common straight pins may be substituted.
   b. Stretching board.
   c. Cork or corrugated pasteboard for lining the bottom of specimen boxes. Pins should be inserted so that the specimens will stand upright in the boxes.

A NET FOR CAPTURING INSECTS



You can make a net like this by using an ordinary bamboo fish pole, a piece of wire, and a yard of mosquito netting or bobbinet.

5. Capturing materials:
   a. Insect net for capturing flying insects. This may be made from mosquito netting, heavy wire, and a stick for a handle.
   b. Aquatic net for capturing water insects.
   c. Bait for attracting night-flying insects. A mixture of molasses and vinegar is often used and may be put on the sides of trees or beside a light.
6. Labels:
   a. Two small rectangular pieces of paper for each insect. On one piece the name of the insect is to be written; on the other, the date and the locality where the insect is caught.

How to preserve a collection. There is little value in collecting insects unless they are preserved for examination and study. A good collection contains both living and dead specimens. The living air-breathing insects may be kept in cages, and the aquatic insects in fish bowls. Dead specimens may either be preserved in bottles containing alcohol or dried and kept in specimen boxes.

How to Use the Suggested Materials

You are familiar with the use of most of the suggested materials, but directions will be given for the preparation and use of some of them. If further help is needed, consult the references at the end of the unit.

The deadly cyanide bottle. The use of potassium cyanide is probably the best method of killing insects, but it is also the most dangerous. It has been said that if a very slight quantity of this chemical comes into contact with an open break in the skin, it will produce almost instant death. Even the fumes, if inhaled in sufficient quantity, will kill people, and they are especially dangerous to people with certain heart disorders. This information is given here so that you may exercise extreme care if you handle this deadly poison.

THE DEADLY CYANIDE BOTTLE

Courtesy *New Wonder World*

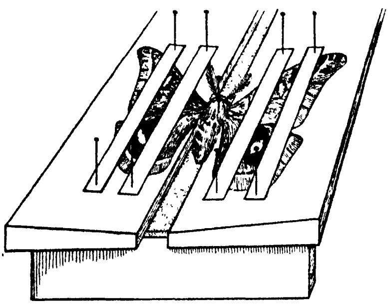
This bottle spells instant death to insects.

Because of the danger involved, you should ask your druggist to prepare your cyanide bottle for you. He will do this by placing several lumps of potassium cyanide in a large-mouthed Mason jar or bottle and by covering the chemical with plaster of paris. Insects die quickly when confined in one of these bottles.

The carbon tetrachloride bottle. You can make your own carbon tetrachloride bottle with very little trouble. First, cover the bottom of a bottle or a wide-mouthed Mason jar with absorbent cotton. Next, cover the cotton with several thicknesses of blotting paper saturated with carbon tetrachloride. Always keep the bottle or jar closed very tightly.

How to prepare insects for mounting. Any insect, such as a moth, should be prepared for mounting soon after it is killed, while its body is still flexible. To do this, place it upon a stretching board and permit it to dry. The wings should be spread out as completely as possible and elevated at a slight angle to the body. They should be held in place by strips of paper laid neatly across them and fastened down at the ends with pins. The wings should never be punctured with pins to hold them in place. Antennae may be held in a lifelike position by pins placed about their edges. Great care must be exercised in placing the legs of a beetle in a lifelike position so that the specimen will look natural.

INSECT STRETCHING BOARD



Courtesy General Biological Supply House

Notice that the soft body of the moth has been placed between the boards and fastened to the base by a pin. Other pins have been placed at the ends of the strips that cover the wings, not through the wings themselves.

Naming and Classifying the Insects

After you have collected a great many insects, you will notice that, while all insects have some parts that are exactly alike, they have other parts that are different. Scientists, recognizing this fact, have classified all insects, as well as other animals, according to the nature of their parts and have given the various groups scientific names. Thus insects are said to belong to a group or class known as Insecta, which is divided into large groups called *orders*. These in turn are divided into *families*. Families are divided into *genera* (jĕn′ẽr-ȧ; singular *genus*, jē′nŭs). Insects that are alike in the nature of all their parts are said to belong to the same *species*.

With the foregoing information you are ready to consider the classification of some of the insects you have studied in this unit. The grasshopper, for instance, belongs to the order called Orthoptera (ŏr-thŏp′tẽr-ȧ), meaning "straight wing."

The parts of the grasshopper which show that it belongs to this order are: (1) a pair of thick front wings which cover a pair of thin hind wings folded up like a fan; (2) chewing mouth parts; and (3) incomplete metamorphosis. The moth and the butterfly belong to the order called Lepidoptera (lĕp′ĭ-dŏp′tẽr-ȧ), meaning "scale wings." The principal features which help to identify insects of this order are: (1) four membranous wings covered or protected by overlapping scales; (2) sucking mouth parts; and (3) complete metamorphosis.

In the Appendix you will find a list of the principal orders of insects together with the essential characteristics by which they may be recognized. A few insects that belong to each order are also named. You may find it helpful to refer to this list as you label the insects in your collection. The labeling should be done on cards about one inch long and five-eighths of an inch wide. Since the cards are small, it will be necessary for you to write or print very carefully. Both the common and the scientific names should be given.

Problem 3. Why are insects of economic importance?

It is impossible to estimate the economic importance of insects. Their contributions to mankind are discussed in the following section. Insects also cause economic losses, as we shall learn through a study of insect pests a little farther on under this problem.

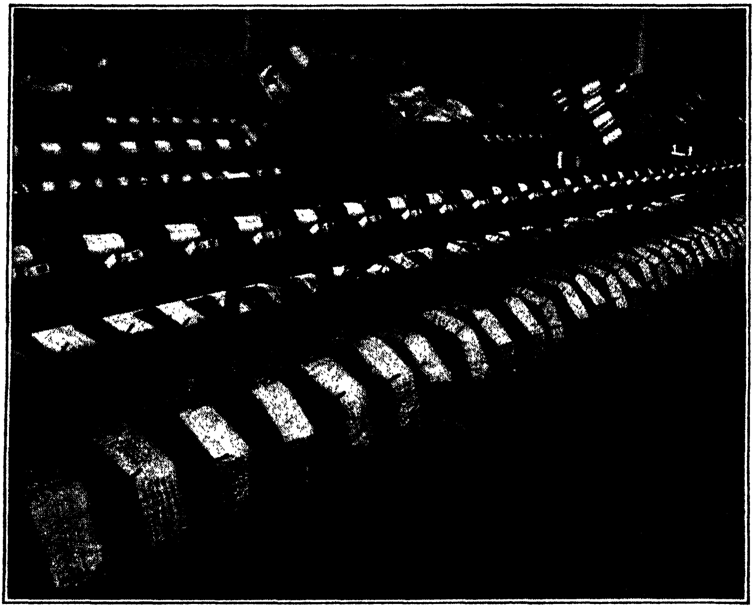
FRIENDS AMONG THE INSECTS

Our friends among the insects are helpful in many ways, both directly and indirectly. They contribute various kinds of clothing and food. By helping to pollinate flowers, they perpetuate plant life that is valuable to human life.

A "WORM" THAT GIVES US CLOTHING

Si-ling discovers silk. It is said that silk was first discovered by an empress of China by the name of Si-ling (sē′lĭng′). This was about twenty-five hundred years before the birth of Christ. One day as Si-ling was walking in her garden she found some

REELING ROOM IN A SILK FACTORY



Century Photos

The silk fibers as they come from the cocoon are entirely too fine to be used for weaving. Many strands must be spun together to make a single thread. This picture shows threads being wound on metal cylinders for use later in making silk cloth.

worms spinning beautiful silken threads. Fascinated by these delicate threads, she thought of the possibility of using them for making garments. Fact may be mixed with fancy in this account of the discovery of silk, but records indicate that Si-ling was the first to encourage the culture of silkworms and the weaving of silk into cloth.

For a long time the secrets of silk production were carefully kept from the rest of the world. Many interesting stories tell how the secrets were finally passed along to India. One of them says that a Chinese princess smuggled silkworm eggs in her headdress into the country when she married an Indian prince. Not until after the Europeans learned about the value of silkworms, however, did the industry become important. Then people studied the scientific rearing of silkworms and

invented machines for reeling and spinning the silk and for weaving the cloth.

The life of the silkworm. The silkworm is the larva stage of the silk moth (*Bombyx mori*, bŏm′bĭks mō′rī). Until recently only one generation of worms a year was produced, but breeders have now developed a variety that produces several generations a year. The female moth lays about three hundred eggs. The worms that hatch from these eggs require a great quantity of food. It has been found that silkworms thrive better upon the leaves of the white mulberry than upon any other food. They have enormous appetites and eat almost constantly. Each worm eats more than its own weight of leaves per day. Thus the leaves from a good-sized mulberry tree feed only about a hundred and twenty-five silkworms. From this quantity of food but three ounces of good silk are usually produced.

STAGES IN THE LIFE OF THE SILKWORM

Ferdinand Hirsh

This picture shows different stages in the life of a silkworm as follows: (1) moth; (2) moth and eggs; (3) small larva or worm; (4) adult larva; (5) larva beginning to spin; (6) finished cocoon; (7) pupa in cocoon.

A full-grown larva or silkworm is about three inches long. While it is eating and growing, it molts or changes its skin four times. When it is slightly over two months old it begins to spin silk by moving its head around in a circular manner. During the first day it completely covers itself with

silken fibers, but it must spin three more days to finish the cocoon. Then the larva molts a fifth time and changes into a chrysalis, which is the beginning of the pupa stage. When the sixth molt occurs, the pupa changes into an adult white moth. A liquid is secreted to loosen one end of the cocoon so that the moth can escape. The change from the pupa to the adult stage of the moth requires a period of about two weeks.

SILKWORMS AND THEIR COCOONS

Ferdinand Hirsh

This picture shows silkworms feeding on mulberry leaves at the lower right. On the stalks above are cocoons ready to be unwound.

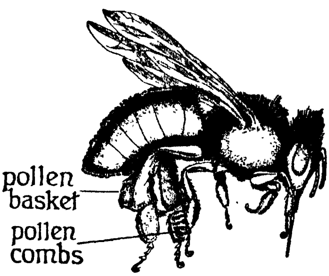
Before a cocoon can be unwound, it must be soaked in water. Fifteen hundred feet or more of silk thread may be obtained from one cocoon.

Keeping the silkworm in health. Silkworms, like all other creatures, are susceptible to disease. Great care must be exercised in feeding them. If there is too much moisture where they are grown, microscopic organisms produce ferments in the leaves of the mulberry which disturb their digestion. Certain microscopic organisms also live in their bodies and attack them. Great losses have occurred in these ways. The industry today, however, is much more secure since Pasteur and others have shown how to prevent disease. Although the silkworm was discovered in China, this nation no longer ranks first in the production of silk. Japan at present is producing about 40 per cent of the world's supply. China now ranks second but is constantly striving to increase production. The silkworm is also cultivated on a less extensive scale in Italy, France, and Germany. A recent substitute for silk, of course, is rayon.

An Insect That Gives Us Food

The honey giver. The bee means much in the life of man. It produces annually about $75,000,000 worth of honey and beeswax. In addition it renders an even greater service in the *cross-pollination* of flowers, that is, the transfer of the pollen of one flower to the stigma of another flower. Although certain plants can pollinate themselves, many of them must be cross-pollinated if fruit and seeds are to develop. The production of some varieties of apples, for example, depends entirely upon cross-pollination of their flowers by bees.

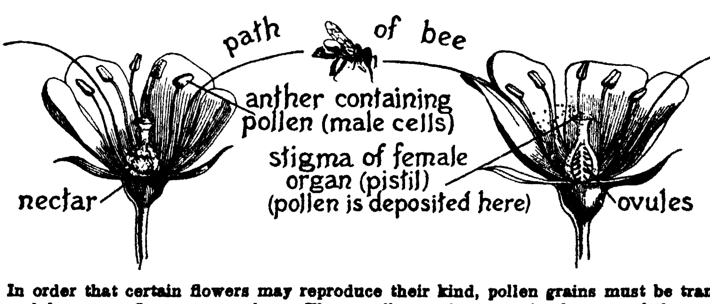
THE BEE'S POLLEN BASKET



The worker bee has combs on its hind legs with which to brush pollen into the pollen baskets on its hind legs.

How the bee picks up pollen. The honey bee is one of the most effective pollinating insects. Its head and body are covered with tiny hairs which pick up pollen as it flies about from flower to flower in search of food. By means of spiny combs on its hind feet it brushes some of the pollen from its body into little baskets on the tibia of its hind legs.

A BEE CARRYING POLLEN FROM FLOWER TO FLOWER



In order that certain flowers may reproduce their kind, pollen grains must be transferred from one flower to another. These pollen grains grow in the part of the male flower called the anther. They must be deposited upon a part of the female flower called the stigma. This is called cross-pollination.

How the bee transfers pollen. It is largely the delicious nectar of flowers that attracts the bee. Doubtless the beautiful coloring is also a factor. The nectar is usually stored in

THE BUMBLEBEE VISITS A FLOWER

Lynwood M. Chace

This bumblebee has come to a clover blossom in search of nectar. Later it will carry to another blossom the pollen that clings to its wings and body.

pools at the base or in the cup of the flower. Thus in order to reach the nectar a bee must reach deep into the flower. In so doing it brushes past the anthers of the flower and picks up some of the pollen. Then it flies to another plant and accidentally drops some of its pollen on the stigma of the pistil. Thus it is that cross-pollination is completed.

In order to reach the nectar at the base of some flowers, such as the red clover, an insect must have a long tongue. It must also be heavy enough to spread the closed petals. The bumblebee has both the long tongue and the necessary weight. As it seeks the nectar, it brings about pollination. When there are few bumblebees, but little clover seed forms. Farmers who realize the truth of this statement often say, "No bumblebees, no clover."

Strange Devices for Pollination of Flowers

Trapped by the lady's-slipper. The lady's-slipper grows wild in rich woodlands. The plant is so named because one of the petals on its flower forms a slipper-like sac. When a bee enters the sac, it is rewarded with a generous supply of nectar. While seeking the nectar, however, it is temporarily trapped by the closing of the bowl of the slipper. As a result it crawls about the inclosure, whirring its wings in an effort to escape. During its imprisonment it picks up considerable pollen from the anthers. Eventually it finds its way out through an exit near the base of the flower and escapes. As it continues its search for nectar and enters another flower it leaves some of the pollen that it has gathered on the stigma.

The mountain laurel "sets its trap." The stamens in the flower of the mountain laurel are bent outward in a springlike manner with their tips anchored against the petals. When a slight pressure is exerted upon the petals, the tips are released and the stamens straighten out. It is the bee that springs these traps, and naturally it gets a thorough dusting with pollen as it does so.

Flowers that are pollinated by insects with tongues a foot long. Certain flowers are so designed as to admit to their nectar pools only insects that can pollinate them. Certain pinks, lilies, and honeysuckles, for example, have their nectar protected by a long tubelike corolla and are pollinated only by long-tongued moths and butterflies. Some of these insects can unroll their tongues to a length of twelve inches, and thus can penetrate the deepest of flowers.

A MOTH WITH A VERY LONG TONGUE

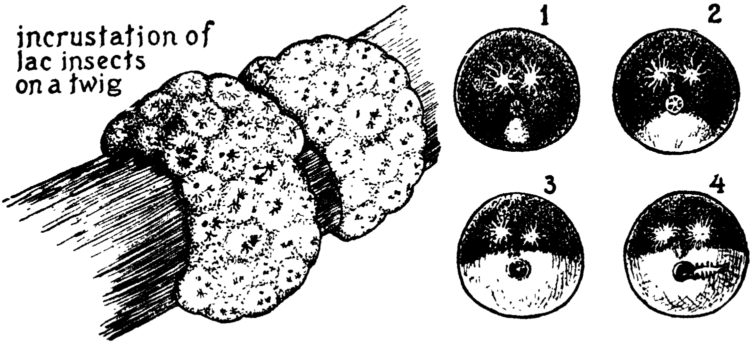
The nectar pools of certain flowers are very hard to reach. When long-tongued moths, such as the hummingbird hawk moth, shown above, reach for the nectar, they cannot avoid bringing about cross-pollination.

The yucca plant a nursery for the pronuba moth. The yucca is a lily-like plant that grows in semiarid regions. Its flower is the home of the white pronuba (prŏn′ū-bȧ) moth. This insect is so much at home here that it lays its eggs in the pistil. It then inserts a pellet or mass of pollen into the stigma, thereby bringing about pollination. This makes it possible for seeds to grow in the flower. The larvae of the pronuba then feed on some of the developing seeds. In this way the yucca plant and the pronuba work together in helping to maintain life.

Other Insect Friends

Insects as a source of shellac. Certain insects, known as lac insects, which grow in India and the East Indies, help us to produce shellac, lac dye, and sealing wax. Their tiny red larvae fasten their beaks into the bark of young twigs and

AN INSECT THAT HELPS TO PROVIDE SHELLAC



This picture shows stages in the life history of a lac insect as follows: (1) resinous shell inclosing a female lac insect; (2) increasing size of translucent spot shows the gradual contraction of insect inside the shell during egg-laying stage; (3 and 4) completion of incubation and emergence of larva.

remain fixed while feeding on the sap. A resinous substance then oozes from their bodies, forming a cocoon-like shell which joins with the coverings of other insects to form an incrustation on a twig. From this incrustation, shellac and various other forms of lac are made, as well as a valuable crimson dye.

One-time friends — the cochineal insects. The cochineal (kŏch′ĭ-nēl) insects are tiny lice that live on the cactus plants of Mexico. We call them our one-time friends because they were formerly a source of carmine dye. Today, however, it is more practical to manufacture dyes from coal tar.

The larvae of the cochineal insects become inclosed in a sac of fluid. The dye is obtained from the dried bodies of these larvae. It may take as many as 75,000 insects to make one pound of dye. Hence it is easy to understand why we resort to other means of obtaining dyes today.

Insects that form galls. Perhaps we have noticed ball-like swellings on the leaves, stems, or twigs of certain vines and shrubs. These swellings are commonly found on goldenrod, blackberry bushes, and certain trees, as the oak, cedar, and spruce. They are called *galls* and are caused chiefly by gall flies, gall wasps, and gall lice. A gall wasp lays its eggs deep in the tissues of the leaves or stems. When the eggs develop into larvae, the near-by plant tissues begin to grow and completely surround them. Thus the plant material of the galls becomes the food supply for the insects. Galls have some economic importance in the production of pigments for ink.

Our scavenger friends. Among our insect friends we must not overlook the scavengers. They perform the useful function of removing and destroying intestinal wastes and dead, decaying organisms. Dung beetles, for example, roll the manure of animals into balls, which they bury as food for their larvae. The quantity they can roll away in a few hours is surprising.

Several species of flies lay their eggs in the bodies of dead animals. These eggs hatch into larvae called *maggots,* which rapidly devour the animals. Blowfly larvae can devour a small dead hog within a week.

Undertakers of the insect world. Carrion beetles are useful in that they help to bury the dead. Observation reveals that they bury many small animals the size of frogs, birds, or mice. After burial they use the dead animals as nurseries for rearing their young.

FOES AMONG THE INSECTS

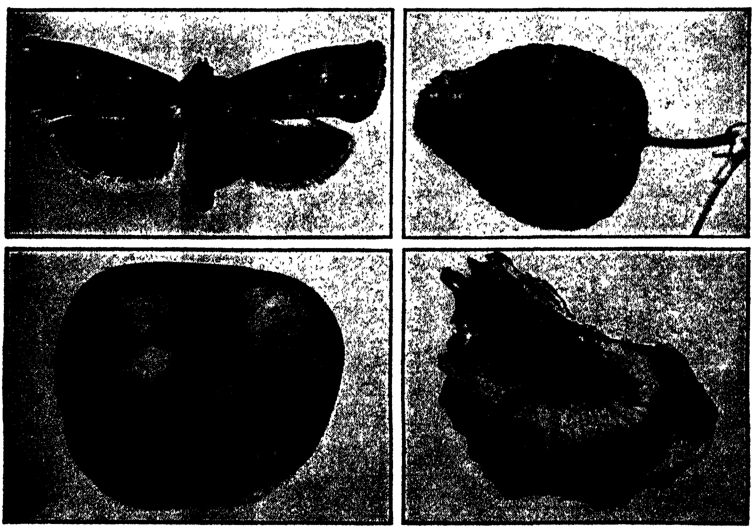
The foregoing should not lead us to conclude that all insects are our friends. In fact, we know from experience that many of them are not. Certain parts of the world are so infested with obnoxious insects that man can scarcely exist there. Great swarms of flies and mosquitoes, for example, inhabit the Arctic region and northern forests in summer and make life miserable for man. Ants, cockroaches, lice, bedbugs, poisonous and stinging insects, and other insect pests are found almost everywhere. Not only do some insects annoy man, but they are even

dangerous in spreading diseases. Others destroy crops. It is estimated that a total of one to one and one-half billion dollars is lost annually in agriculture because of insect pests.

The beetle that punctures fruit. The plum curculio (kûr-kū′-lĭ-ō) is a beetle scarcely one-fourth of an inch long. It is brown in color, with black and yellow spots. Fruits, such as plums, cherries, peaches, apricots, and grapes, are damaged to the extent of $9,000,000 annually through the attacks of this pest. The loss comes from the fact that the beetle punctures the fruit for the purpose of laying its eggs. Further damage is done to the fruit by the larvae of curculios after they hatch from the eggs.

The apple eater—the larva of the codling moth. The codling moth is one of the most destructive pests and annually ruins about $25,000,000 worth of apples. In late spring the

STAGES IN THE LIFE OF AN APPLE EATER
THE CODLING MOTH



Courtesy U. S. Department of Agriculture

The first picture at the left above shows an adult codling moth such as frequents an apple orchard in the late spring. The first picture at the right shows eggs which the moth has laid on a leaf. The lower left-hand picture shows a larva inside an apple. The lower right-hand picture shows the larva ready to spin a cocoon.

little brown moth lays its eggs upon the leaves or blossoms of an apple tree. Each egg hatches into a larva, which bores its way into the forming fruit, where it feeds for several weeks. Finally it bores a hole out of the apple and into the open. Then it hides in the bark of a tree or other protected place, spins a cocoon, and settles down for the winter. In the spring a new moth makes its appearance from the cocoon.

Why blame the bee? Because bees have been found sucking the juice from grapes, plums, and cherries, these insects have been falsely accused of stinging fruits. It has been proved, however, that they do not puncture the fruits and that they merely suck the juice through the openings made by plum curculios.

The pest of the cotton crop. The boll weevil is probably our most destructive agricultural pest, causing a loss of several hundred million dollars a year in the cotton crop. The adult beetle lays its eggs in the cotton buds and also in the more matured cotton bolls. The buds then fall off and never develop. The damaged bolls may stay on the stem, but the cotton fibers will be discolored.

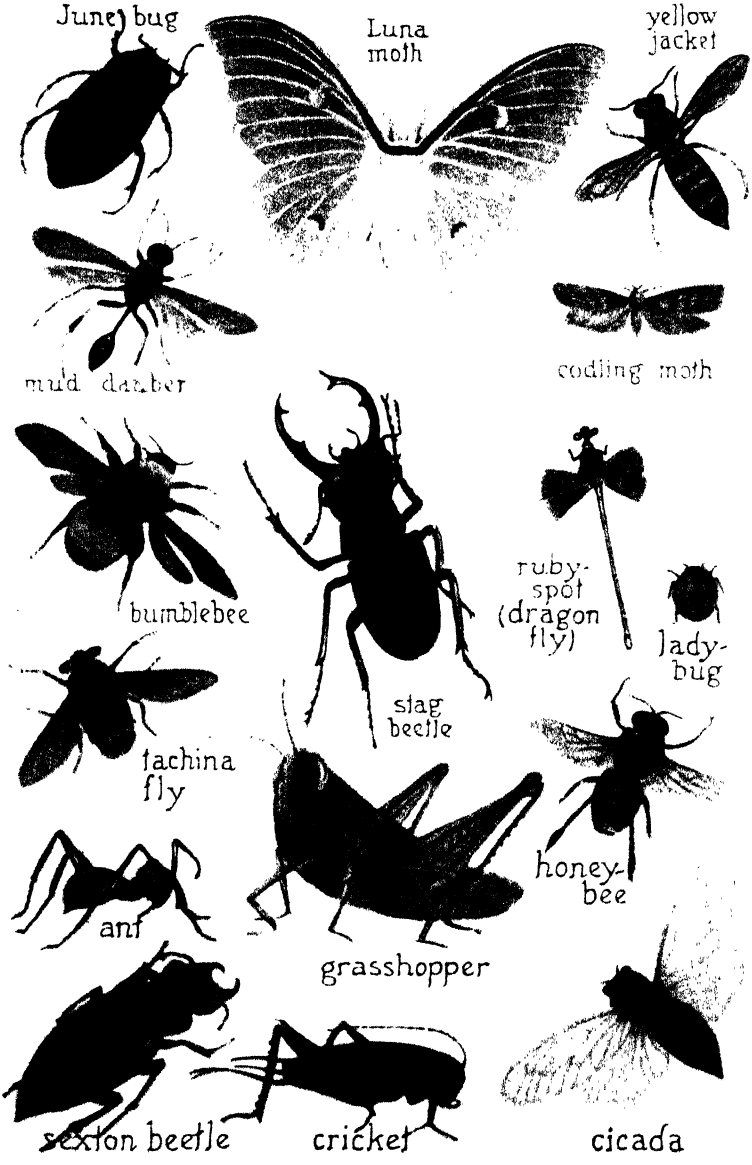
Potato beetles in "convention." Occasionally a farmer plants potatoes in a patch of ground that has not had potatoes planted in or near it for several years. He may think that his vines will be safe from the attacks of the Colorado potato beetle. Probably, however, he will be disappointed, for as soon as the vines appear the beetles will "decide to hold a convention." They will broadcast throughout the territory

THE PEST OF THE COTTON FIELDS

Underwood & Underwood

The cotton boll weevil lays its eggs in the young flower buds. In three or four days the grubs hatch, causing the infested buds to fall to the ground. The larvae then pass through the pupa stage and develop into adults.

JUMPERS, CRAWLERS, AND FLYERS



that this convention will be held at the potato patch, and soon many delegates will arrive.

The adult beetle winters in the ground. It emerges in the spring and deposits orange-colored eggs upon a potato vine. In about ten days these eggs hatch into larvae which eat ravenously, thereby stripping the vine of its leaves and causing it to die. In three weeks the insect passes into the pupa stage. Here it remains for two weeks, after which an adult emerges ready to start a new generation.

OTHER INSECT PESTS

Common Name of Pest	Obnoxious Feature	Stage of Life Cycle in Which the Insect Is a Pest
Field pests		
European corn borer	Weakens cornstalks, causing them to break	Larva
Corn earworm......	Damages the silks and kernels of corn	Larva
Army worm.......	Eats grasses; one species also attacks wheat heads	Larva
Wireworm	Feeds on roots of plants	Larva
Hessian fly........	Weakens the straws of small grains	Larva
Chinch bug........	Eats grasses and cereal crops	Larva and adult
Grasshopper.......	Eats leaves of many plants	Adult
Cutworm..........	Gnaws off the stems of tender plants at the surface and feeds on roots	Larva
Mole cricket[1]......	Feeds on roots	Adult
Garden pests		
Striped cucumber beetle...........	Larva eats roots and stems, and adult eats leaves of plants belonging to the melon family	Larva and adult
Squash bug........	Eats squash vines	Adult
Aphid (plant louse).	Sucks juices of tender plants	Adult
Cabbage butterfly..	Feeds on leaves of plants of the mustard family, especially cabbage	Larva
Tomato worm.....	Feeds on leaves of potato, tomato, and tobacco	Larva
Shade tree pests		
Gypsy moth.......	Eats leaves	Larva
Catalpa sphinx moth	Eats catalpa leaves	Larva
Brown-tailed moth.	Eats leaves	Larva
Bark beetle........	Bores holes in bark and sapwood	Larva
Tussock moth......	Eats leaves	Larva

[1] The changa of Puerto Rico.

OTHER INSECT PESTS—*Continued*

COMMON NAME OF PEST	OBNOXIOUS FEATURE	STAGE OF LIFE CYCLE IN WHICH THE INSECT IS A PEST
Fruit tree pests		
Gypsy moth	Eats leaves and destroys fruit	Larva
Brown-tailed moth	Eats leaves	Larva
San Jose scale	Sucks juice from twigs	Adult
Peach-tree borer	Bores into bark of peach, cherry, and plum	Larva
Mediterranean fruit fly	Eats living tissues of fruits	Larva
Tent caterpillar	Eats leaves; makes webs in trees	Larva
Oyster shell scale	Sucks juices from bark of young twigs and leaves of apple and pear trees	Adult
Mealybug	Feeds on leaves, twigs, and fruit of orange, lemon, and grapefruit trees	Adult
Parasitic pests		
Louse (pl. lice)	Spreads relapsing fever, typhus fever, and trench fever; sucks blood	Adult
Oxwarble fly	Bores holes in hides of cattle	Larva
Horsefly	Bores holes in hides of horses and sucks blood	Adult
Bedbug	Sucks blood from human beings	Adult
Flea	Sucks blood; spreads bubonic plague	Adult
Household pests		
Ant	Enters cupboards and gets upon food	Adult
Cockroach	Enters cupboards and carries disease germs to food	Adult
Carpet beetle	Makes holes in carpets	Larva
Clothes moth	Makes holes in clothing	Larva
Meal worm	Eats flour, corn meal, cereals	Larva
Fly	Spreads disease germs	Adult
Mosquito	Sucks blood from animals	Adult

Problem 4. How can insect pests be controlled?

It requires a wide variety of methods to control and exterminate insect pests. Methods have been devised, however, for each of the insects listed in the foregoing table. Each method must be adapted to the nature of the insect. The mosquito, for example, can best be exterminated in the larval stage of its life cycle. Destruction of breeding places is more effective than swatting in controlling the fly.

METHODS OF EXTERMINATION AND CONTROL

Usually a knowledge of the structure and habits of insect pests is essential to extermination and control. If the larvae of the codling moth are to be killed, for instance, apple trees must be sprayed before the young fruit is formed. Spraying later is ineffective, because the larvae are safely imbedded in the apples, where they cannot be reached by the spray.

Biting insects that chew and eat leaves may be poisoned by certain poisons placed upon the leaves. This method, however, is of no avail in fighting sucking or piercing insects, since they take their food from the interior of the plant. To kill these insects, it is necessary to use contact poisons, which poison them through the skin or which close their spiracles and cause suffocation by forcing them to inhale poisonous fumes. Contact poisons will also kill biting insects, since they, too, breathe through spiracles.

Combating Insects with Chemicals

Chemical warfare by use of stomach poisons. Arsenic is probably the chief ingredient used in making stomach poisons for killing insects on plants. Lead arsenate, for example, is a white poisonous powder that may be sprinkled on the leaves or mixed with water and used as a spray. Another common stomach poison is Paris green. This poison is very effective, but it does not stick well and it is hard to apply evenly because its green color is hard to distinguish from that of leaves.

Chemical warfare by use of contact poisons. The standard contact poisons are lime-sulfur, kerosene-soap emulsion, and various tobacco preparations. Lime-sulfur kills by its corrosive action upon the skin; the kerosene-soap emulsion kills by clogging the breathing pores; and tobacco preparations kill by poisoning through the skin.

A kerosene-soap emulsion is commonly used because it is so easy to make. A one-inch cube of laundry soap is dissolved in a pint of water. Then a pint of kerosene is added. The mixture is usually called "stock." When used, it is diluted in the ratio of one part of stock to three parts of water.

A standard tobacco preparation may be bought under the name of nicotine sulfate. It can be used effectively upon all true bugs, scale insects, and plant lice. Lime-sulfur may either be purchased or prepared by hand.

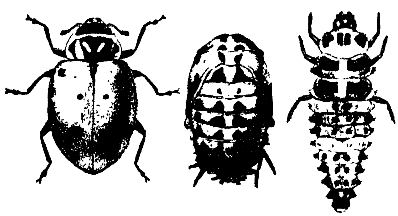
Combating Insects by Fumigation

In greenhouses, grain elevators, and places where it is possible to confine vapors and gases, insects can be readily killed by fumigation. For this purpose cyanide gas is most effective, but is so dangerous that it must be used only by an expert. Carbon bisulfide is also quite effective. Its fumes are not so poisonous to man, but it is explosive and consequently must be handled with care.

Using Insects to Combat Insects

Can insects be used to fight insects? The answer is yes, and furthermore this method of combating insect pests is coming to the fore very rapidly. Insects which either kill certain other insects or prey upon them as parasites are known as *predaceous*.

AN ALLY OF MAN—THE LADYBIRD



Courtesy United States Department of Agriculture

The useful ladybird preys upon destructive plant lice. The illustration shows from left to right the adult form, the pupa, and the larva.

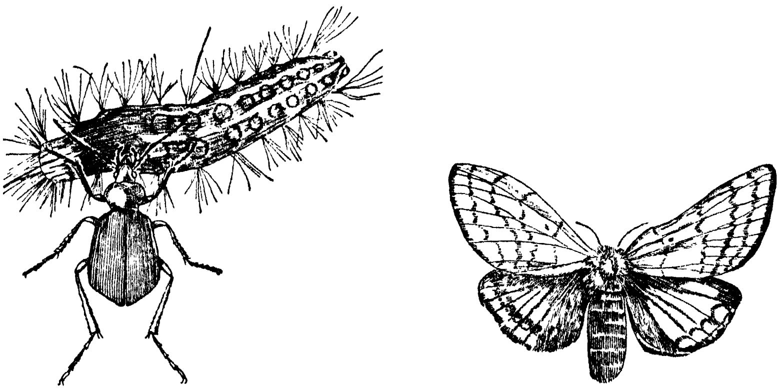
State experiment stations and the United States Department of Agriculture are making strenuous efforts to find insect enemies of insect pests. If, for example, insect pests are accidentally imported, an entomologist (ĕn′tō-mŏl′ō-jĭst) goes to the country from which the insects came and searches for their natural enemy. If an enemy is found, it is shipped in egg, larva, pupa, and adult stages to our agricultural stations, where it is grown in great numbers. Then eventually it is released as a predaceous insect.

How the ladybird helps us. Nearly all species of the ladybug or ladybird beetles may be considered our friends. They are good friends, too, for they hold in check the cottony-

cushion scale that attacks citrus fruit trees. Scientists imported the ladybug from Australia because that was the original home of the cottony-cushion scale. Another species of ladybug is sucessfully used in fighting plant lice.

Other predaceous friends. The ichneumon (ĭk-nū′mŏn) fly is a parasite upon the tent caterpillar. It lays its eggs within the caterpillar, and the larvae that hatch from them feed upon the caterpillar and destroy it. In a similar manner the tachina

THE CALOSOMA BEETLE DINING ON THE LARVA OF THE GYPSY MOTH



The calosoma beetle was imported from Europe to rid trees of the pest the gypsy moth. The upper drawing at the left shows the larva of the gypsy moth and the lower one, the calosoma beetle. The drawing at the right shows the adult gypsy moth.

(tăk′ĭ-nȧ) fly checks the spread of the army worm, and the calosoma (kăl-ō-sō′mȧ) beetle checks the gypsy moth. Certain parasitic wasps have been found to prey upon the boll weevil.

Combating Insects by Crop Adjustment

Crops may be planted at such a season that they will mature before their respective insect pests are in the proper stages to attack them. For instance, if cotton is planted early, it will mature before the cotton boll weevils are very active. If plants are kept healthy, they can withstand insect attacks better than they can if they are dwarfed or weak. The rotation of crops tends to prevent tracts of land from becoming too highly infested with insects that pupate in the soil.

SUGGESTED ACTIVITIES

I. Self-Organization Summary

A. Characteristics and Life Habits of Insects

1. Prepare a three-column chart as follows: In the first column list the body regions of a typical insect; in the second column list the external parts that are located in each of these regions; and in the third column list the function of each of the parts.
2. Trace the life history of a grasshopper.
3. Trace the life history of the tiger swallowtail butterfly.

B. Collecting and Identifying Insects

1. What materials are necessary for making an insect collection?
2. How may these materials best be used?
3. Prepare a three-column chart as follows: In the first column list six of the more important orders of insects, in the second column state the characteristics of each order, and in the third column give one or more examples of each order. (Several orders of insects, together with a brief description of each, are listed in the Appendix.)

C. The Economic Importance of Insects

1. Summarize useful insects by preparing a chart similar to the one in this unit that summarizes insect pests. (See pages 199–200.)
2. Explain the destructive work of the plum curculio, codling moth, boll weevil, potato beetle, European corn borer, and Mediterranean fruit fly.

D. Methods of Insect Control

1. How do the methods of control for biting insects differ from those for sucking insects?
2. What four common methods of insect control are presented in this unit? Explain each one.

II. Laboratory Study

A. An insect collection. This may be made either as a group project or as an individual one. Your instructor will tell you whether you are to label your specimens with family, genus, and species names or whether you are to limit classification to the sorting into orders and listing of common names only.

B. Dissections and drawings to show the parts of insects and their uses. Confine your study to general anatomy only.
C. Microscopic examination of such parts of insects as wings, feet, and head parts.

III. Display Posters

A. Habitat charts of pictures of insects and the places in which they live. For example, on a card headed "Field Insects," you may paste pictures of such insects as grasshoppers, katydids, beetles, crickets, and flies. Other habitats, such as "Pond and Brook," "Orchard," and "Forest," may be selected.
B. Cardboard picture charts of life cycles.
C. Two charts, one of "Insect Friends" and another of "Insect Foes." Through research these may be made to include many more forms than are given in the text.
D. Other picture collections of interest:
   1. Insects of unusual colors
   2. Insects of unusual size
   3. Pictures of each of the main orders
   4. Pictures of mechanical equipment necessary to administer poisons to insects

IV. Special Reports

A. Other interesting life cycles
B. Special insect friends and foes
C. Additional methods of controlling insect pests
D. The relation of insects to disease

REFERENCES[1]

1. Beard, Daniel C. *American Boys' Book of Bugs, Butterflies and Beetles.*
   a. How to collect insects, pp. 30–54
   b. The butterfly and moth family, pp. 54–66
   c. American silkworms, pp. 66–100
   d. Lowest, degraded bugs, pp. 270–277
   e. Leaf and tree hoppers, pp. 280–288
   f. Water bugs, pp. 289–299

[1] The pages listed are those found in the editions indicated in the alphabetical list of references given at the end of this book.

2. Carpenter, George H. *The Biology of Insects.*
   a. Feeding and breathing, pp. 15–47
   b. Sensation and reaction, pp. 69–94
   c. Reproduction, pp. 114–150
   d. Classification, pp. 306–325
   e. Insects and mankind, p. 418

3. Carpenter, George H. *Insects: Their Structure and Life.*
   a. The form of insects, pp. 1–65
   b. The life history of insects, pp. 65–100
   c. The classification and evolution of insects, pp. 100–237
   d. Insects and their surroundings, pp. 237–284

4. Comstock, John Henry. *Insect Life.*
   a. The parts of an insect, p. 9
   b. The collection and preservation of specimens, pp. 22–51, 284–315
   c. Classification of insects, pp. 51–87
   d. Insect pond life, pp. 87–144
   e. Brook life, pp. 144–166
   f. Orchard life, pp. 166–186
   g. Forest life, pp. 186–221
   h. Roadside life, pp. 221–284
   i. The breeding of insects, p. 336

5. Metcalf, C. L., and Flint, W. P. *Fundamentals of Insect Life.*
   a. The internal anatomy and physiology of insects, pp. 98–119
   b. The mouth parts of insects, pp. 119–141
   c. Insect control, pp. 364–417

6. Pickwell, Gayle. *Western Nature Study Series: Insects.*
   a. Insect structures, pp. 7–24
   b. Insect foods and feeding habits, pp. 42–57
   c. Insect voices, pp. 122–135
   d. Collecting and preserving insects, pp. 271–280

7. Wellhouse, Walter H. *How Insects Live.*
   A technical study of the various orders of insects with interesting sidelights

8. *Book of Popular Science, The.*
   a. Insect against insect, Vol. 15, pp. 5059–5070
   b. Some beautiful winged insects, Vol. 14, pp. 4803–4813

9. *Compton's Pictured Encyclopedia.*
   a. Insect pests and their cost to man, Vol. 7, pp. 89–90
   b. Some mysteries of insect life, Vol. 7, pp. 91–94
10. *New Wonder World, The.*
   a. Butterflies, moths, and other insects, Vol. 3, pp. 119–129
   b. How to capture, kill, and mount insects, Vol. 3, pp. 377–382
11. *World Book Encyclopedia, The.*
   a. Silk and the silkworm, pp. 6604–6611
   b. The boll weevil and its control, pp. 823–825

VISUAL AIDS

Films (16 mm.)

A. Eastman Teaching Films, Inc., Rochester, New York.
   1. Housefly. 15 min. 1 reel, silent, $24.00.
      Presents the life history of the fly together with information concerning its dangerous habits and methods of keeping it under control
   2. Silk. 1 reel, silent, $24.00.
      Pictures the work of the silkworm

B. Erpi Picture Consultants, Inc., 250 West 57th Street, New York City.
   1. Pond Insects. 1 reel, sound, $50.00.
      Illustrates the life cycles and food habits of a variety of water insects
   2. Beetles. 1 reel, sound, $50.00.
      Develops the economic relation of typical beetles

C. Herman A. DeVry, Inc., 1111 Center Street, Chicago, Illinois.
   1. Butterflies and Moths. 1 reel, silent, $24.00.
      Presents the life histories of the Monarch butterfly and the Cecropia moth

D. Bell and Howell Company, Chicago, Illinois.
   1. Life Cycle of the Ant Lion. 1 reel, sound, $1.50 per day.

Charts

A. The Balslev-Anderson (Insect) Series. Titles: Hymenoptera, Hemiptera, Lepidoptera, Diptera and Neuroptera, Coleoptera. Nos. II and III, Orthoptera.

UNIT SIX

LIFE PROCESSES IN PLANTS AND ANIMALS

SUGGESTIONS TO THE TEACHER

This unit is a study of the fundamental life processes. A knowledge of these processes is necessary for a complete understanding of many other biological facts and principles. For purposes of motivation and clarity, the life processes of a living machine are compared with the workings of a man-made machine. Both consume fuel, develop energy, and carry on work.

As the student studies this unit, he will learn how plants manufacture food. Then he will learn how the food provides the fuel from which plants and animals derive energy for the preservation of life and for the doing of work. In other words, he will learn how food enables plants and animals to carry on all the functions that distinguish them as living organisms.

OBJECTIVES

I. Facts and principles

A. To learn that plants and animals have in common certain processes or functions, such as:

1. Taking in food and eliminating waste
2. Growth
3. Irritability
4. Movement
5. Repair
6. Reproduction

B. To learn how living things differ from nonliving things

C. To develop an understanding and an appreciation of the great diversity among living things

D. To learn about the structure and function of plants and animals in relation to life processes

E. To compare specialization and division of labor in simple and complex organisms

F. To study the hygiene and sanitation involved in the proper functioning of life processes

II. Attitudes

A. To build up a matter-of-fact attitude toward life processes

B. To develop an appreciation of good health

UNIT SIX

LIFE PROCESSES IN PLANTS AND ANIMALS

A LIVING MACHINE AT WORK

Ewing Galloway

This elephant is using energy in moving logs. As you study this unit, you will find that many of the processes carried on by living machines, such as the elephant shown above, resemble those of man-made machines, such as a gasoline engine.

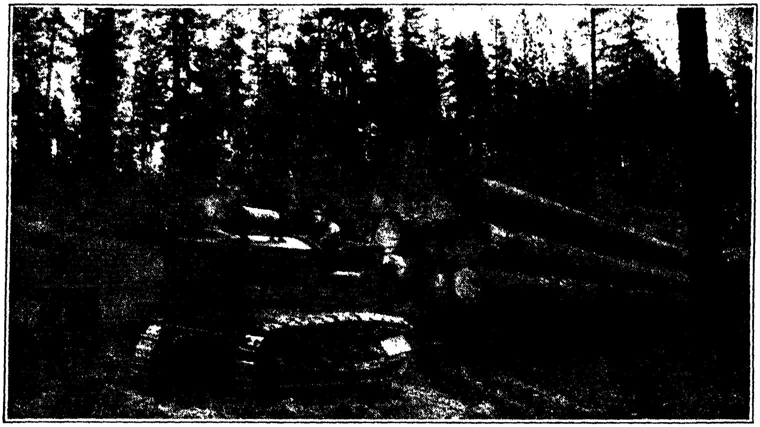
THE ELEPHANT AND THE MOTOR

PREVIEW

Has it ever occurred to you that an animal, such as the elephant, is somewhat like a motor? Indeed, every living organism, even man himself, is somewhat like a motor. Every organism has certain functions that resemble those of a machine. Let us see what some of the functions are.

The elephant is large and strong. Usually it is docile and easy to manage. As a result, people in certain parts of the world use it to do heavy kinds of work. The above picture,

A MAN-MADE MACHINE AT WORK



The tractor in this picture is pulling logs through a large forest in the West. In other words, the gasoline engine in the tractor is developing and using energy to do work much like that being done by the elephant in the picture on the preceding page.

for example, shows an elephant moving logs. How, we may inquire, does the elephant get its capacity to do work? It eats large quantities of food, principally grasses and grains. The food passes along the digestive tract, where it is converted into soluble form. Then it is assimilated and carried to the tissues, where it is oxidized or burned, producing heat, energy, and waste. The heat gives the elephant its normal temperature. The energy gives it the capacity to do work. The waste, of course, is eliminated. To summarize, the elephant can do work because its body takes in food and converts a certain part of it into energy.

Now let us consider the work of a machine, such as a gasoline engine. The above picture shows a tractor pulling logs. The tractor derives its power from a gasoline engine. The engine must have gasoline just as an elephant must have food. The gasoline, like the food, must be digested. Therefore it is carried to a part of the engine known as the carburetor, where it is vaporized and mixed with air. Then it passes to the cylinders, where it is burned, producing heat, energy, and waste. The heat is carried away by a cooling system.

The energy is used in doing work, such as moving a truck or automobile or turning the wheels of a factory. The waste is eliminated through the exhaust.

It is evident, from the above discussion, that the elephant and the gasoline engine operate in a very similar manner. Both take in fuel and transform it into heat, energy, and waste. Both use the energy in doing work. Likewise, any other living organism, even a mosquito or a fly, may be compared with a motor. The comparison is somewhat ridiculous, but the same general principles apply.

The foregoing discussion leads us to inquire: What are the chief processes of living machines? How do they resemble those of man-made machines and how are they different? The answers may be derived by a consideration of the following problems.

PROBLEMS

1. **What constitutes a living machine?**
2. **How is fuel produced for the operation of living machines?**
3. **What fuels do living machines consume?**
4. **How do living machines transform foods into actual sources of energy?**
5. **How is fuel carried to points of use in living machines?**
6. **How is oxygen supplied to the cells and how is carbon dioxide removed?**
7. **How are wastes removed from living machines?**
8. **What use is made of energy by living machines?**
9. **How may living machines be kept in efficient operation?**

Problem 1. What constitutes a living machine?

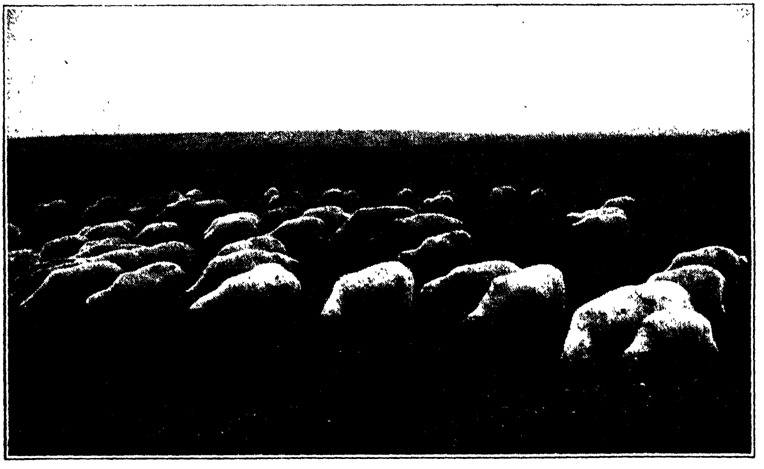
As we compared the work of the elephant in carrying logs with that of the gasoline engine in dragging logs, we noted the similar functions listed on the following page.

1. Intake of fuel
2. Preparation of the fuel for use
3. Burning of the fuel
4. Expenditure of energy

CELLS, TISSUES, AND ORGANS

Now let us examine the entire list of processes involved in the operation of a living machine, either plant or animal. As we consider these processes, we shall discover still other ways in which living organisms resemble man-made machines.

TAKING ON FUEL



These sheep are grazing contentedly in a pasture, but more specifically they are eating food which will enable them to carry on the fundamental processes of life.

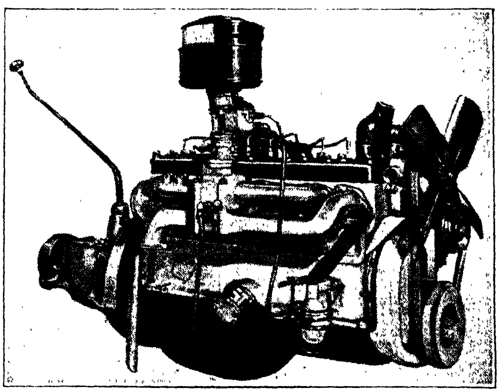
1. *Food getting,* or intake of fuel.
2. *Digestion,* or preparation of the fuel for use. This corresponds somewhat to the vaporization of fuel by the carburetor of a gasoline engine.
3. *Circulation,* or conveyance of the fuel to the place in which it will be used.
4. *Respiration,* or intake of oxygen and release of carbon dioxide.
5. *Excretion,* or removal of the waste products.

6. *Motion,* or the consumption of stored energy.
7. *Assimilation,* or the conversion of food into living protoplasm. This process cannot be carried on by a man-made machine.
8. *Nervous control,*[1] or the regulatory system of a living machine. The fine mechanism for controlling a motor is somewhat similar to the nervous system of a living body, but we must remember that a man-made machine cannot control itself.
9. *Reproduction,*[1] or the process by which a living machine brings forth others of its kind. This function has no parallel in a man-made machine, and is one of the chief differences between living and nonliving matter.

The total functioning of the first seven of the foregoing processes is called *metabolism* (mê-tăb′ô-lĭz'm). In other words, metabolism is the sum of the processes concerned in the building up and tearing down of protoplasm in a living machine.

Division of labor in machines. The various parts of a man-made machine are designed to perform definite functions. For example, the carburetor of an automobile mixes air with the gasoline; the ignition system provides an electric spark for the explosion of vaporized gas; the transmission system transfers power from the engine to the shaft that drives the wheels; and the exhaust removes the wastes.

A MACHINE THAT PRACTICES DIVISION OF LABOR



Each part of a gasoline engine, such as this in an automobile, performs a definite function.

[1]The nervous system and the reproductive system are not discussed in this unit because they do not fit into the mechanical comparisons that are made. These topics are treated in Units Ten and Eleven, but may be studied in close sequence with Unit Six if a connection seems desirable.

Labor is divided in much the same way in a multicellular living organism. Certain parts of the body of a plant or an animal prepare food for absorption and oxidation; other parts take in oxygen, and still other parts remove wastes.

THE BUILDING BLOCKS OF LIVING MACHINES

Cells. The specialization of the various parts of plants and animals comes from the fact that all living machines are built of *cells*. Each of these cells is capable of performing all life processes. In many instances, however, as we shall learn later, certain cells work together as a group to perform special functions.

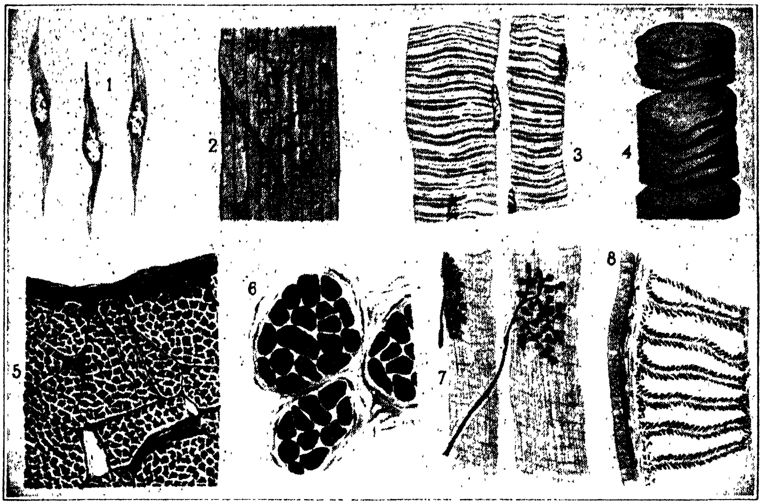
Cells may be defined as the building blocks or units of living matter.[1] In shape they are commonly rectangular, spherical, or cylindrical. In other words, they all have length, breadth, and thickness.

The parts of a cell. The principal parts of a cell[2] are the cell wall, nucleus, protoplasm, cytoplasm, vacuoles, plastids, centrosome, chromosomes, nucleolus, and nuclear membrane. The real substance of the cell is the *protoplasm*. This substance is held within the cell by a thin membrane known as the *cell wall*. The denser part of the protoplasm is called the *nucleus*, and is usually in or near the center of the cell. The remainder of the protoplasm, exclusive of the nucleus, is called the *cytoplasm*. Within the nucleus are the *chromosomes*, which carry the hereditary characters of the cell, and the *nucleolus*, which is a globular or spherical body. The exact function of the nucleolus is not known. *Vacuoles* are spaces in the cell which contain air, food, water, or waste material. The *centrosome* lies near the nucleus and aids in the division of the cell. The *plastids* are bodies, scattered throughout the cytoplasm, that carry on or aid in carrying on certain metabolic processes. The *nuclear membrane* surrounds and gives shape to the nucleus.

[1] Although scientists are learning of smaller divisions of living matter than the cell, to select it as the building unit of the bodies of plants and animals is sufficiently scientific.

[2] Cell structure has been presented in Unit Two. It is repeated here in order to give a connected story of life processes.

MUSCLE CELLS AND TISSUES OF THE ANIMAL BODY



Smalian Histologic-Embryologic Chart—Courtesy A. J. Nystrom & Company

1. Smooth cells of involuntary muscle
2. Longitudinal section of a group of cells of a striated (voluntary) muscle
3. Single striated muscle fibers showing striations and nuclei greatly magnified
4. Crushed fibrillae that make up the striated muscle fibers
5. Cross section of striated muscle fibers showing individual fibrillae and tissue surrounding them
6. Greatly magnified view of a few fibrillae together with the tissue surrounding them
7. Two striated (voluntary) muscle fibers showing on each the branched endings of a nerve fiber, which transmits to the fibrillae the impulse to act
8. Cross section of the outer portion of the earthworm showing the epidermis (outer skin) and the muscles by means of which it moves. Beneath the nucleated epidermal cells (at the left) lies the muscle tissue which encircles the earthworm's body and which, when it contracts, lengthens the body. At the right are shown the muscles which run lengthwise of the body and which, when they contract, shorten the body. The alternation between the lengthening and shortening of its body makes it possible for the earthworm to crawl.

Cells That Work Together

Tissues and organs. An aggregate of cells of similar structure constitutes a *tissue*. Thus the bones, skin, brains, and muscles of animals and the bark, leaves, and stems of plants are composed of tissues. A group of tissues that performs a special function or work, as the stem of a plant or the heart of man, is called an *organ*. An organ, then, is composed of several kinds of tissue. A single-celled plant, of course, has no organs because it has no tissues.

Problem 2. How is fuel produced for the operation of living machines?

The world's food supply. How many of us, while eating a delicious meal, ever stop to think of the source of our food? Every dish contains food obtained directly or indirectly from plants. Even a steak or roast comes indirectly from the plants that an animal has eaten. This fact may lead us to ask the question, "If all life depends on plants, where do they in turn get their food?" Since most plants live in or near the ground, the most natural answer is: "From the soil." When we recall, however, that the food of both plants and animals consists of *proteins, fats,* and *carbohydrates* (starches and sugars), we know that such food materials cannot be obtained directly from the soil. Thus, if sugar existed in the soil, we should probably mine it just as we do certain minerals. The truth of the matter is that plants take certain substances from the soil and from the air which they manufacture into proteins, fats, and carbohydrates for their own use.

PHOTOSYNTHESIS

The manufacturing of carbohydrates. If plants manufacture the world's food supply, then factories must exist within their bodies. Upon investigation we find that such is the case—that the structure of green tissues and especially of leaves is designed for manufacturing food.

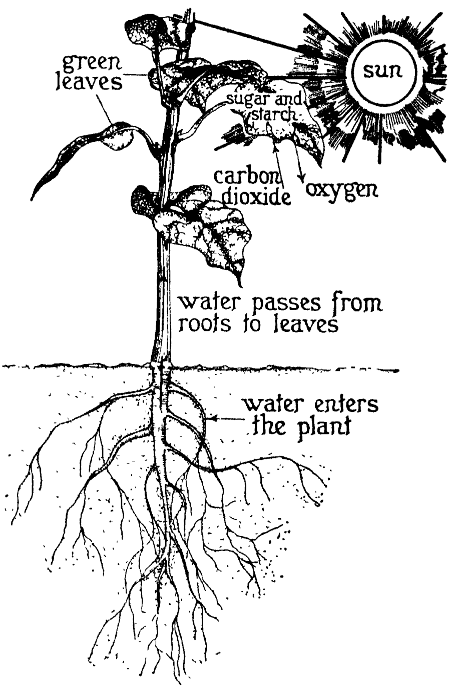
The production of sugar by green plants is called *photosynthesis.* The "photo" part of this word signifies that such manufacturing occurs only in the presence of sunlight; and "synthesis" means, in this case, a binding together of certain elements of the air and soil. To carry out the process of photosynthesis, a regular factory set-up with raw materials is provided as follows:

1. *The factory*—green tissues, especially the leaves.
2. *The machine rooms*—special cells capable of bringing about photosynthesis. In a leaf these are called mesophyll (mĕs′ō-fĭl) cells.

3. *The machinery — chlorophyll* and *chloroplasts.* The chlorophyll is the green coloring matter, and the chloroplasts are plastids containing the chlorophyll.
4. *The energy* — sunlight.
5. *The raw materials* — carbon dioxide (CO_2)* and water (H_2O).
6. *The finished products* — sugar ($C_6H_{12}O_6$) and starch [$(C_6H_{10}O_5)_n$].
7. *The waste material* — oxygen.

The chemical production of sugar and starch. A green plant having leaves, stems, and roots secures carbon dioxide (CO_2) from the air, through its leaves, and water (H_2O) from the soil, through its roots. The water is transported from the roots through the stems to the leaves. Here, in the presence of sunlight and chlorophyll, these compounds are broken down within the special manufacturing cells (mesophyll cells) into their separate atoms. The carbon dioxide (CO_2) is broken up into separate atoms of carbon and oxygen, (C-O-O), and the water (H_2O) is broken up into separate atoms of hydrogen and oxygen, (H-H-O). Then certain quantities of

THE PLANT FACTORY AT WORK

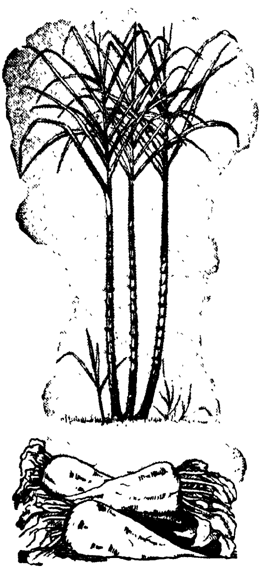


What is photosynthesis? What materials does a plant use in the process of photosynthesis?

*The chemical formula CO_2 means that a molecule or a unit of carbon dioxide contains one atom or one part of carbon to two atoms or two parts of oxygen, Chemical compounds are also represented by chemical formulas.

the carbon dioxide (CO_2) and the water (H_2O) recombine in such a way as to produce sugar and release oxygen as a by-product. Such a union of substances is called *chemical reaction* and is represented by the following equation:

PLANTS THAT MAKE SUGAR



Sugar cane and sugar beets. What chemical elements are present in sugar?

$$\underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} = \underset{\text{sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2}$$

This equation means that the atoms contained in six parts of carbon dioxide and in six parts of water unite to form one part of the compound sugar and six parts of oxygen. Further chemical changes in a plant may result in a transformation of this sugar ($C_6H_{12}O_6$) into starch [$(C_6H_{10}O_5)_n$]. This is the form in which carbohydrates are usually stored in plants.

The manufacture of fats. Evidences that plants use fats are found in the commercial extractions from plants of such fats as linseed oil, cottonseed oil, castor oil, peanut oil, and cocoa butter. Strange to say, plants have no machinery for the direct production of fats. Such foods are thought to be produced by chemical changes in the carbohydrates. Thus the fats or oils in plants, like the starches, are really in storage form. They must be changed in form before plants can use them as food.

The manufacture of protein. Protein is another storage form of plant food. There is no actual machinery for its production, but it is probably made in many parts of a plant. It does not come alone from a recombination of the elements of carbon, hydrogen, and oxygen, which compose the carbohydrates, but contains in addition nitrogen and small quantities of such elements as phosphorus and sulfur.

Although about four-fifths of the air about us is composed of nitrogen, plants cannot use it in gaseous form. They must

get it from nitrates[1] in the soil. Nitrates are needed in all cells to form protoplasm. Some plants take up such large quantities of nitrates and other elements, as sulfur and phosphorus, that they reduce the fertility of the soil. Then it becomes necessary to use fertilizer.

PLANTS THAT MAKE PROTEINS

Peas and beans. What chemical elements are used by plants in manufacturing protein?

Doesn't it seem miraculous that a large part of our food is only a combination of water and carbon dioxide? If this is the case, the absence of what essential substance makes it impossible for us to produce sugar by blowing our breath, which contains carbon dioxide, into a pan of water?

THE FOOD FACTORY OF PLANTS

INSPECTING THE INSIDE OF THE FACTORY — LEAVES

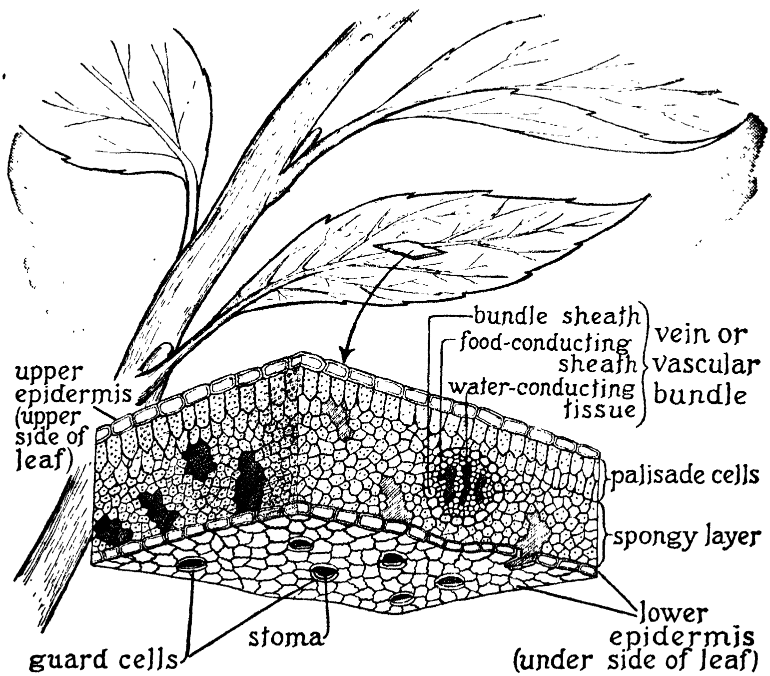
The importance of photosynthesis. Let us next look inside a plant's food factory by examining under a microscope the tissues of a typical leaf. The top layer of tissue is called the *upper epidermis*. This is the roof of the factory, and the function of its close-fitting cells is to protect underlying tissues. Beneath the roof is one or more than one layer of cells that stand erect like palisades and are called *palisade cells*. Here most of the machinery (chloroplasts and chlorophyll) for photosynthesis is located. Beneath the palisade cells is a *spongy layer* of irregular cells. Numerous air spaces between the cells make possible a thorough diffusion of gases throughout the layer, as well as along the ends of the palisade cells. The cells of

[1]Nitrates — certain compounds containing nitrogen.

the spongy layer contain fewer chloroplasts than the palisade cells and therefore carry on less photosynthesis. The palisade and spongy tissues together are called the *mesophyll.* Between the cells of the mesophyll are scattered groups of conducting tubes called *veins.* The lower lining of the leaf, known as the *lower epidermis,* might also be called the breathing layer, for it contains the *stomata* (stō′mȧ-tȧ; singular, stō′mȧ), or openings through which the plant carries on part of its respiration. The stomata are controlled by *guard cells* which regulate the passage of gases into and out of the leaf.

During photosynthesis plants use carbon dioxide, which they obtain from the air, and give off excess oxygen as a by-

LEAF PARTS INVOLVED IN FOOD MANUFACTURE



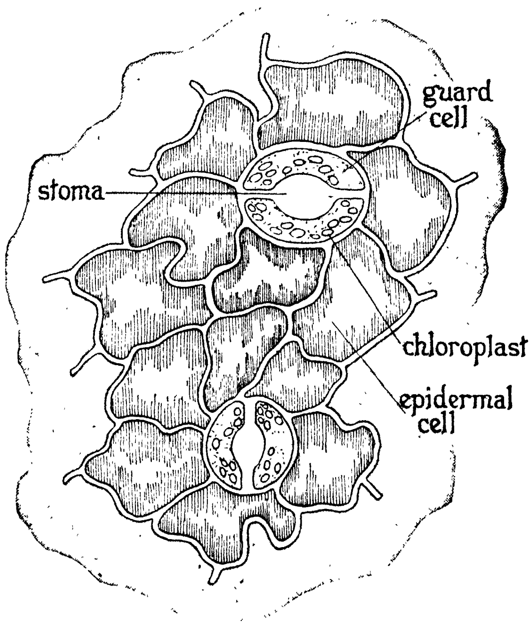
This drawing shows several leaves and a small section of a leaf highly magnified. How does each layer in the section function in the process of photosynthesis?

product. They also lose by evaporation through the stomata some of the water that comes up from the roots by way of the stems. This loss of water is called *transpiration.*

THE TRANSPORTATION SYSTEM OF THE PLANT FACTORY—STEMS

Rôle of stems. Two of the chief functions of stems are the transportation upward, to the leaves, of raw materials taken in by the roots, and the conduction, downward, to places of storage and use, of foods manufactured in the leaves. Thus we may think of stems as having elevators that carry fluids upward and food products downward. The elevators, however, are really tubes. Groups of them are called *vascular bundles.* The arrangement of vascular bundles in stems forms one of the bases for classifying flowering plants into the two great groups called *dicotyledons* (dī-kŏt′ĭ-lē′dŭnz) and *monocotyledons* (mŏn′ô-kŏt′ĭ-lē′dŭnz).

GUARD CELLS AND STOMATA ON THE LOWER EPIDERMIS OF A LEAF



The opening and closing of the guard cells regulate the interchange of such gases as carbon dioxide and oxygen. The guard cells also control the escape of moisture from the leaf.

A *dicotyledonous plant* is one in which the *embryo* (ĕm′brĭ-ō)[1] within the seed has two primary leaves called *cotyledons.* The vascular or conducting tissue is arranged in a circle about a

[1]Embryo—an organism in a very early stage of development.

central *pith.* The leaves of dicotyledons have netted veins. A *monocotyledonous plant* has an embryo with only one cotyledon. The vascular or conducting tissue is arranged in bundles scattered throughout the stem. There is no central pith. The leaves of monocotyledons have parallel veins. Most of our trees and shrubs and such herbs as the sunflower, clover, bean, and aster are dicotyledons. Grasses, corn, sugar cane, bamboo, wheat, palms, and bananas are monocotyledons.

The structure of a dicotyledonous stem. There are usually four layers of tissue in the cross section of a dicotyledonous stem:

1. Epidermis, or outside layer
2. Cortex, or layer between the epidermis and conducting layer
3. Conducting layer
   - phloem
     - phloem fibers
     - sieve tubes
   - cambium
   - xylem
     - wood fibers
     - tubes
       - ringed
       - spiral
       - pitted
4. Pith

1. The *epidermis* consists of a single layer of cells, and is found only in young stems.

2. The *cortex* (côr′tĕks), in a young stem, is made up of thin-walled cells called *parenchyma* (pȧ-rĕn′kĭ-mȧ). These cells in plants like the sunflower contain chloroplasts and hence help carry on photosynthesis. (See illustration on the following page.) As the stem increases in diameter, the epidermis is replaced by *cork cells* which develop in the outer part of the cortex. These cells contain substances that prevent both water and gases from entering the stem. In the bark of trees and shrubs are loose groups of cells known as *lenticels* (lĕn′tĭ-sĕlz) which assist in respiration. These cells are important, especially in winter when there are no leaves to help in breathing, the intake of oxygen and the outgo of carbon dioxide.

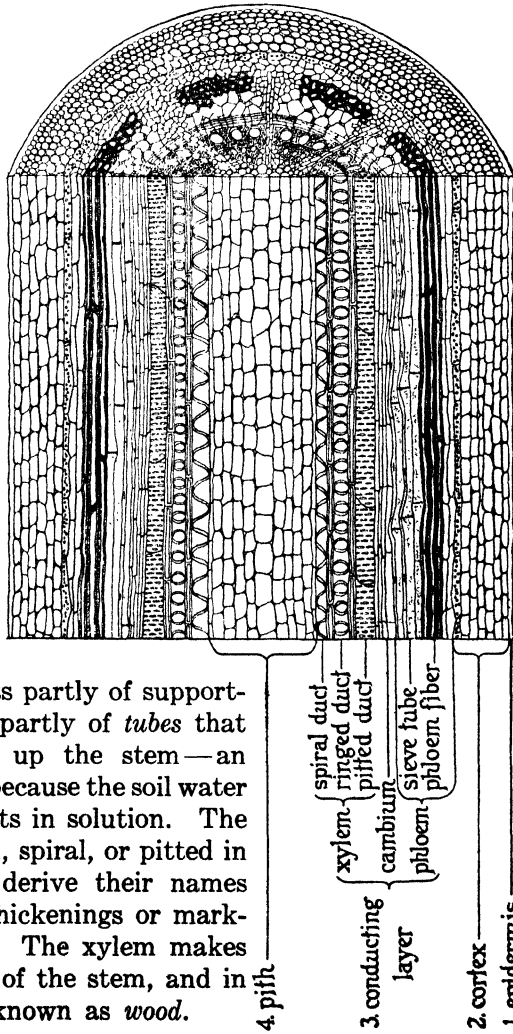
3. The *conducting layer* is made up of vascular tissues which may or may not be arranged in bundles. Each bundle consists

of three tissues—phloem (flō′ĕm), cambium (kăm′bĭ-ŭm), and xylem (zī′lĕm). The *phloem* is the tissue toward the outside of the stem through which food is conducted downward. The *xylem* is the tissue toward the inside of the stem through which water is conducted upward. The *cambium* is a single layer of cells which lies between the phloem and xylem.

The phloem consists chiefly of *sieve tubes* and *phloem fibers,* sometimes called *bast fibers.* The sieve tubes are thin-walled cells with sievelike cross walls through which manufactured foods flow on their way to places of use or storage.

The xylem consists partly of supporting *wood fibers* and partly of *tubes* that conduct soil water up the stem—an important function because the soil water contains mineral salts in solution. The tubes may be ringed, spiral, or pitted in appearance. They derive their names from the types of thickenings or markings on their walls. The xylem makes up the greater part of the stem, and in trees is commonly known as *wood.*

THE INTERIOR OF THE STEM OF A DICOTYLEDON

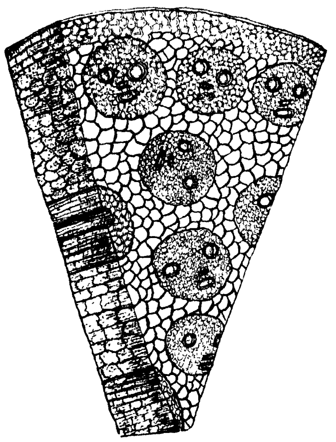


The *bark* of a young tree includes the epidermis, cortex, and phloem. As the stem of a tree becomes older, the epidermis entirely disappears because of the increase in the diameter of the stem and the growth of the cortex.

The cambium lies between the xylem and the phloem and gives rise to xylem and phloem tissues. This is the growing layer responsible for the increase in diameter of stems. The distinct rings that may be seen in a cross section are called *annual rings.* They ordinarily represent the growth made in one year through the activity of the layer of cambium cells.

4. The *pith,* or center of the stem, is made up of thin-walled parenchyma cells that serve as storage places or passageways for food. *Medullary* (mĕd′ŭ-lā-rĭ) *rays* are parenchyma cells that extend from pith to cortex and separate the vascular tissues. Their function is similar to that of the pith.

CROSS SECTION OF STEM OF A MONOCOTYLEDON



Courtesy Denoyer-Geppert Company

In this type of stem the vascular bundles are scattered through the pith.

Structure of a monocotyledonous stem. The stem of a monocotyledonous plant consists primarily of parenchyma cells. The vascular bundles, instead of developing a definite layer as in the dicotyledonous plants, are scattered throughout the stem. Each vascular bundle has xylem, or water-conducting tubes, toward the center of the stem and phloem, or food-conducting tubes, toward the outside of the stem. Thick-walled woody cells usually surround the bundles. The tubes are essentially the same as those in dicotyledonous plants. There is no cambium layer, however, as in the case of dicotyledons; consequently the growth of the stem is not revealed by annual rings. Nevertheless, each stem has an epidermis and an inconspicuous cortex with breathing pores.

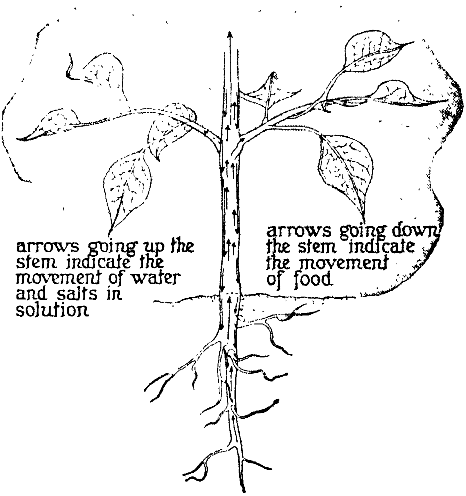
Important Facts to Remember about Stems

Dicotyledonous Plants	*Monocotyledonous Plants*
Cambium layers present	No cambium layers present
Central pith	No definite central pith layer
Grow in height; also by annual increases in diameter when plants live more than one year	Grow in height chiefly; no annual increases in diameter
Bundles in definite layers	Bundles more or less irregularly scattered

The Transportation Tubes in Operation

The tubes of the xylem are filled with soil water and dissolved mineral salts. The tubes of the phloem contain the manufactured sugar solution. We may think of the contents of the xylem tubes as continuously flowing upward to the leaves during photosynthesis, whereas the contents of the phloem tubes are flowing downward at all times during the growing season. Food must be in solution to be transported. The soil water containing mineral salts and the liquid food materials within a plant are called *sap*.

THE PLANT'S TRANSPORTATION SYSTEM AT WORK



Soil water and dissolved mineral solutions (raw materials) pass upward in the stem from the roots to the leaves. The finished products (manufactured food) pass downward to places of storage and use.

The flow of fluids in trees seems almost miraculous. In certain trees sap rises to a height of over three hundred feet! It may move from side to side as well as up and down. In leaves water combines chemically with carbon dioxide to form sugar. This sugar solution is then carried to the trunk, branches, and roots. Here it may be converted into starch or fat and stored for

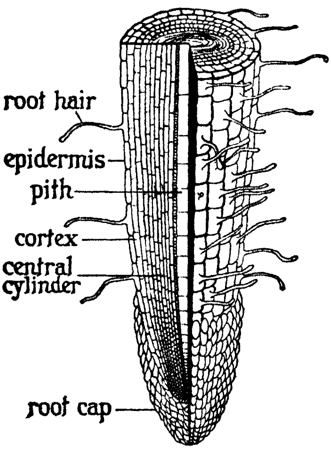
future use. When spring comes, some of the food stored in the plant is converted back into sugar and sent up the stem to the very tips of the branches. Here it is used in the development of unfolding buds.

THE RECEIVING ROOM AND STOREHOUSE OF PLANTS — ROOTS

The water-conducting and food-conducting tubes of stems are continuations of the same kinds of tubes in roots. Thus the flow of foods and raw materials is going on in much the same manner in roots as it is in stems.

Absorption of raw materials by roots. The absorbing surface of roots is greatly increased by tiny elongations of the epidermal cells known as *root hairs.* Through them vast quantities of water and substances dissolved in water are taken into the plant.

ROOT PARTS INVOLVED IN FOOD MANUFACTURE



This diagram shows a cross and a longitudinal section of a root. The root hairs absorb mineral solutions which the plant uses in making food.

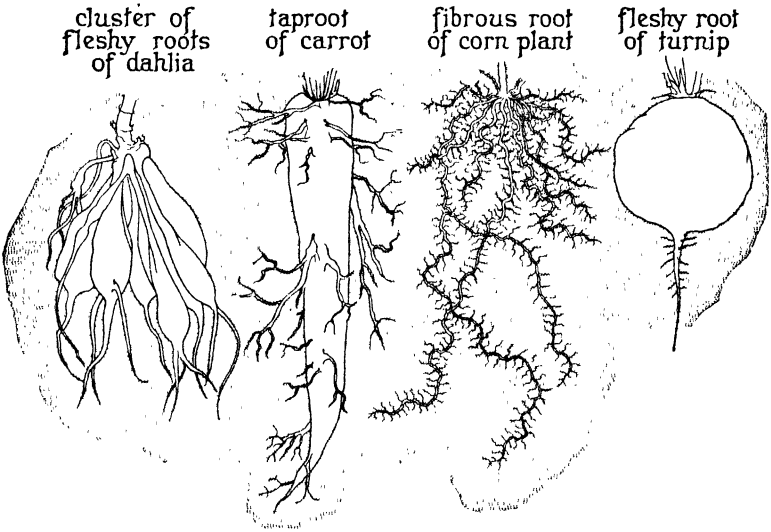
The cell wall of a root hair is made up of complex material. When such material takes up water, it swells. The absorption of water by organic material and the swelling which results from it are called *imbibition* (ĭm′bĭ-bĭsh′ŭn).

Particles of liquids and gases tend to distribute themselves evenly throughout a space by the process of *diffusion.* This means that particles move from the places where they are numerous to places where they are less numerous. When the diffusion takes place through a membrane, the process is known as *osmosis* (ŏs-mō′sĭs). By this process, water from the earth diffuses through the walls of the cells in the root hairs. This intake of water is aided further by the process of transpiration in the leaves. The combination of osmotic (ŏs-mŏt′ĭk) pressure in the roots and

the "pull" of transpiration in the leaves causes fluids in plants to rise. The roots also help to carry on respiration.

The storage of food in roots. In many plants, roots serve as the chief storage places of food. The roots of the beet,

TYPES OF ROOT



How are these roots adapted to food storage, anchorage, and absorption? Which are the best adapted for storage? for anchorage? for absorption?

turnip, carrot, dahlia, and sweet potato, for instance, are peculiarly adapted for storage purposes. Since roots of this kind are enlarged, they are called *fleshy roots.* Sugars are usually changed to starch when stored as food, but converted back before they are consumed.

According to form, roots are classified as *taproots* and *fibrous roots.* A taproot has a large descending axis with smaller branches extending from its sides. A fibrous root is one in which the main root and its branches are about the same size. The carrot has a taproot, whereas corn has slender fibrous roots. In some plants, as the dahlia, the fibrous roots are fleshy because they store food.

Problem 3. What fuels do living machines consume?

Living machines differ from man-made machines in that they must not only take in sufficient food for the requirements of energy but must also make provision for growth and body repair. Thus we think of the foods of living machines as being of two types: (1) those that supply fuel or energy and (2) those that provide for growth and repair. Even these foods, however, as we shall soon see, are not sufficient for the perfect operation of living machines.

PRINCIPLES OF DIETETICS

All the substances taken into a living body to make it function properly are called *body requirements*. The most important of these substances and their functions are the following:

1. *Fuel foods.* These are the carbohydrates and fats, which release energy when oxidized.
2. *Growth and repair foods.* These are the proteins, which when assimilated provide new protoplasm for an increase in the size of an organism or for repair of worn-out tissues.
3. *Water.* This is the fluid that provides for the transportation of foods throughout the body of an organism and assists in the chemical changes of metabolism.
4. *Oxygen.* This is a gas that is essential for the burning up of foods and the consequent release of energy.
5. *Vitamins.* These are organic substances in foods which are essential to growth, nutrition, and the prevention of disease.
6. *Salts.* These are mineral compounds that serve as activators or regulators in keeping living machines in good working order. Examples of elements contained in some of these salts are calcium, phosphorus, iron, and iodine.

How the Food Requirements of Human Machines Are Determined

The fuel requirements of man-made machines can be measured very accurately. For example, a gallon of gasoline

will carry a certain make of automobile fifteen miles on a level road. If the road should run up a mountain side, the car will need more gasoline to cover the same distance. Likewise, the food requirements of human machines to meet the needs of daily life have been accurately determined.

The unit of measure for these calculations is the *Calorie* (kăl′ō-rĭ),[1] the amount of heat required to raise the temperature of one kilogram (2¼ pounds) of water 1° Centigrade. It has been determined by dietetic experiments that the minimum number of heat units necessary for the existence of life is approximately one Calorie per kilogram of body weight per hour. Thus a man weighing 75 kilograms, or 167.5 pounds, normally requires 1,800 Calories ($75 \times 1 \times 24$) a day to maintain life processes.

The process of determining the energy a man requires is rather complicated. He must be placed inside a respiration chamber which registers the amount of oxygen he consumes in twenty-four hours. This amount is equivalent to the number of Calories produced by the burning of his food during the same twenty-four hours.

How fuel requirements vary. We must remember that 1,800 Calories represent only the minimum number necessary for the basic processes going on in the human body. It is necessary to add additional Calories for certain factors that vary in different individuals. For instance, persons engaged in work requiring great muscular activity need more Calories than those who work at desks. In general, boys require more Calories than girls. Size, or body surface, also has a bearing upon the need.

DAILY CALORIE REQUIREMENT

KIND OF WORK DONE	WOMEN	MEN
No work done—resting most of the day	1,600	2,000
Work done at desks	2,000	2,200
Work done while standing or walking	2,200	2,700
Work requiring considerable muscular exertion	2,500 to 3,000	3,000 to 6,000

[1] This Calorie should not be confused with the small calorie, which is the amount of heat required to raise the temperature of 1 gram of water 1° Centigrade.

The figures on the preceding page are only averages. In general, a high-school girl needs about 2,400 Calories a day, a high-school boy about 2,700 Calories.

WHY FUELS SHOULD BE ADAPTED TO THE MACHINES IN WHICH THEY ARE BURNED

Ratio of proteins, fats, and carbohydrates. People today are less concerned with exact ratios and Calories than they were a few years ago. The important factor is that the diet be adapted to individual needs. It must contain an abundance of carbohydrates and small quantities of proteins and fats. In general, there should be one Calorie of fat to four Calories of carbohydrates, and 10 to 15 per cent of the total daily Calories should consist of proteins. The ratio, however, must fit the individual case. Some individuals, for example, do not digest and assimilate starches well; others take care of these foods with apparent ease.

The appetite is a fairly reliable guide to what a person should or should not eat. He should not, however, rely upon it entirely. The real effects of a faulty diet may not show up for years. It apparently is responsible directly or indirectly for such diseases as ulcers, cancer, gallstones, and hyperacidity. Therefore we should select our foods very carefully.

Excessive proteins in the diet seem to be toxic and produce putrefaction in the large intestine. Most adult individuals should eat sparingly of proteins, especially meats. Two or three ounces (70 to 75 grams) a day have been found sufficient.

Diet an important factor in treatment of disease. Diet is a very important factor in the treatment of many diseases. It is also considered important in the prevention of disease and in the maintenance of good health.

By consulting the published results of current studies by reliable dietetic experts, we may keep abreast of the times in the selection and use of foods. A further safeguard is to have an annual physical examination, followed by proper dietetic (dī′ĕ-tĕt′ĭk) information which will enable us to avoid mistakes in diet that may prove damaging to certain organs of our bodies.

Planning a typical diet. It may prove interesting to use the table below for constructing an average daily diet. Below the table is a suggested form in which to write the names of various foods with their corresponding Calories. The diet is to contain 2,700 Calories divided in proper ratio. Such a diet will suit the needs of the average high-school student.

Kind of Food	Average Serving	Carbohydrate Calories	Fat Calories	Protein Calories	Total Calories
Bacon	3 slices	....	87	13	100
Beans	1 serving	150	8	42	200
Beef (broiled)	1 serving	....	104	96	200
Blackberries	1 cup	150	32	18	200
Bread	1 slice	40	3	7	50
Butter	1 pat	....	99	1	100
Buttermilk	1 glass	24	6	15	45
Cabbage	1 serving	7	1	2	10
Cheese (American)	1 ounce	3	63	23	89
Chicken	1 serving	....	49	51	100
Dates	5	91	7	2	100
Eggs	2	....	90	50	140
Figs	4	188	2	10	200
Grapefruit	½	89	4	7	100
Ham	1 serving	....	106	44	150
Lamb	1 chop	....	60	40	100
Macaroni	1 serving	42	1	7	50
Milk	1 glass	24	44	17	85
Oatmeal	1 serving	45	11	11	67
Oysters	5	20	18	37	75
Peanuts	25	18	63	19	100
Plums	4	95	....	5	100
Potato (baked)	1	178	10	12	200
Trout	1 serving	....	52	81	133
Walnuts (English)	15	7	82	11	100

A TYPICAL DIET[1]

Food Selection	Carbohydrate Calories	Fat Calories	Protein Calories	Total Calories
Breakfast	....	....	....	....
Lunch	....	....	....	....
Dinner	....	....	....	....
Grand totals	....	....	....	2,700
Ratio	4:1		10% of total calories	

[1]The diet should be worked out on a separate sheet of paper.

THE VALUE OF ALKALINE-PRODUCING FOODS IN THE DIET

Another factor of importance in the selection of foods is the prevention of *acidosis* (ăs'ĭd-ō'sĭs). This is a condition of the blood caused by excessive oxidation of acid-forming foods, principally proteins, such as meat and eggs. The body tends

ACID-PRODUCING FOODS

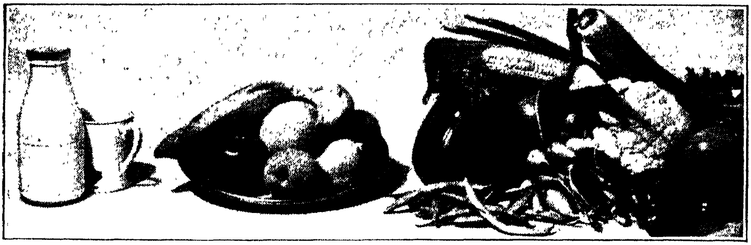
Foods such as these shown above do not have an acid taste, but they produce an acid effect in the body. To what class do most acid-producing foods belong?

to rid itself of the excess acid through the exhalation of carbonic acid gas from the lungs, the pouring forth of an acid sweat by the skin, the excretion of a highly acid urine by the kidneys, and the secretion of highly acid juices by the stomach. When one is suffering from acidosis, the mouth becomes acid, with consequent injury to the teeth, the stomach is sour, and the muscles and brain cells become fagged because of inability to throw off accumulations of harmful substances in their tissues. Such diseases as kidney disorders, high blood pressure, and apoplexy may be aggravated by the eating of acid-forming foods over a long period of time.

In addition to their tendency to produce acidosis if taken in too large quantities, proteins, when not absorbed, produce intestinal putrefaction and decay. This probably results in the absorption of toxic products harmful to bodily functions.

Acidosis may be counteracted by the inclusion of alkaline-producing foods in the diet. Chief among these foods are milk and most of the fruits and vegetables. The question is frequently asked, "How can fruits that contain citric and malic acids act as alkalizers in the blood?" The answer is that,

ALKALINE-PRODUCING FOODS



Foods like these help to counteract a condition of acidosis. What are some of the foods? To what classes do most alkaline-producing foods belong?

although these foods are acid in the intestinal tract, alkaline salts are left in the blood after absorption and oxidation have taken place. It is evident, then, that we should include plenty of alkaline-producing foods in our diet. We should not, however, become faddists, for uncooked fruits and vegetables may be entirely too rough for the digestive tract.

Vitamins—Our Health Guardians

Even though we select the proper proportion of proteins, fats, and carbohydrates and limit ourselves to the correct number of Calories chiefly from alkaline-producing foods, our diet will be inadequate if it does not contain sufficient *vitamins* (vī′tȧ-mĭnz). Although some of the vitamins are not fully understood chemically, they are known to be tiny substances essential to growth, nutrition, and the preservation of health. They are not proteins, fats, or carbohydrates, nor are they inorganic salts. Their presence, however, seems to promote healthful chemical reactions and to prevent certain diseases.

Vitamins are named according to the letters of the alphabet, accepted groups being referred to as A, B, C, D, E, and G. Probably others will be discovered.

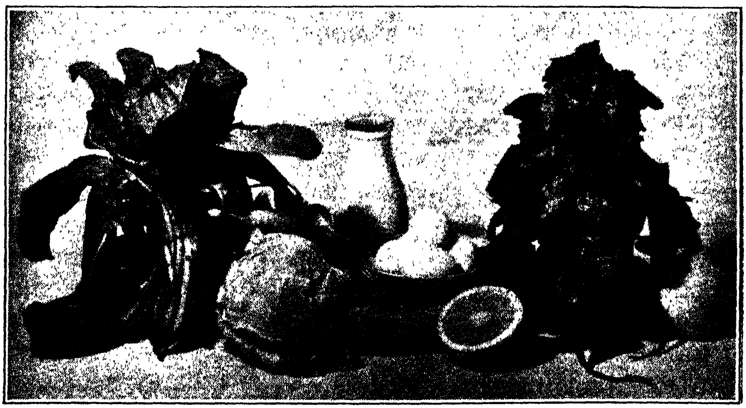
The lack of vitamins a cause of disease. We have learned about vitamins from dietetic experiments upon animals and observations of the effect of diet upon man. For example, in such eastern countries as Japan and China, where the average diet consists largely of polished rice, many people develop a

nervous disorder called *beriberi* (bĕr′ĭ-bĕr′ĭ). Since the disease seldom occurs in places where unpolished rice is eaten, we may conclude that certain healthful substances are removed from rice in the refining process.

Until our knowledge of vitamins developed, sailors frequently suffered from attacks of *scurvy* as a result of eating canned and preserved foods. By taking aboard ship fresh fruits and vegetables, they are able to prevent the occurrence of this disease. *Night blindness*, *pellagra* (pĕ-lăg′rȧ) (skin and nervous disorder), *ophthalmia* (ŏf-thăl′mĭ-ȧ) (eye disease), and *rickets* (a disease of the bones) are other diseases resulting from a lack of vitamins.

The vitamin that prevents certain eye diseases—vitamin A. In promoting growth and body weight and in the prevention of night blindness and ophthalmia, vitamin A is a very important substance. The beginning of ophthalmia can be detected when the tear glands cease to produce tears. This causes the eyes to become dry and leads to ulceration of the cornea (kôr′nē-ȧ),

FOODS CONTAINING VITAMIN A



The foods shown above are rich in vitamin A. What foods do you see? What is the value of vitamin A in the diet? Does cooking affect vitamin A?

which in turn may cause the lens to come out, thereby destroying the sight. Usually associated with the disease is an excessive dryness of the mouth and throat which makes it almost impossible for the victim to eat.

Although vitamin A is called a fat-soluble vitamin, it is not present in all fatty foods. It is commonly found in butter, whole milk, green leaves of vegetables, such as lettuce, beets, and spinach, cod-liver and halibut-liver oil, egg yolk, and a few fruits, such as peaches. Only small quantities occur in animal fats and lean meats or in vegetable oils. Vitamin A is, however, abundant in liver, sweetbreads, and kidneys. Ordinary cooking destroys very little of it, but prolonged heating in air completely destroys it.

The vitamin that prevents beriberi — vitamin B. Recently it has been discovered that the so-called vitamin B is really two

FOODS CONTAINING VITAMIN B

Leafy, root, and tuber vegetables, peas, beans, tomatoes, and other foods rich in vitamin B are shown. Why should these foods be included in our diet?

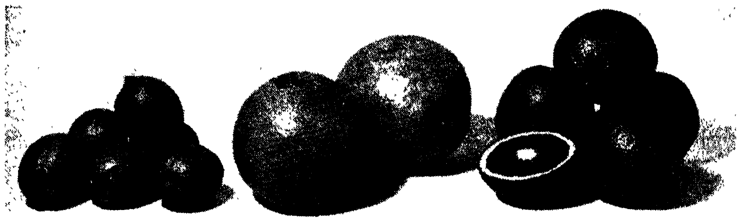
vitamins, B_1 and B_2, now referred to as B and G.[1] The first of these cannot withstand high temperatures so long as the second. Commercial canning does not destroy appreciable quantities of either one. Vitamin B is found in leafy, root, and tuber vegetables and in such glandular organs of animals as the liver, brain, or kidneys. Fruits, cereals, beans, peas, corn, yeast, and lettuce are good sources. Lack of vitamin B results chiefly in beriberi, which, we have already learned, is a nervous disorder resulting in many complications.

The vitamin that prevents scurvy — vitamin C. Unlike vitamin B, vitamin C does not withstand heat in the presence of oxygen, and ordinary canning destroys it. Therefore, to

[1] B_1 has also been called vitamin F.

secure vitamin C, one should eat an abundance of uncooked green vegetables and drink juices of raw fruits. Orange and lemon juices are considered excellent sources.

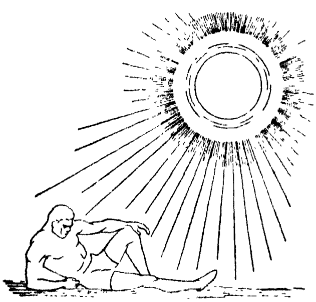
SOURCES OF VITAMIN C—CITRUS FRUITS

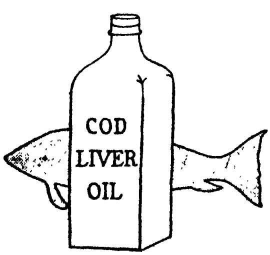


Mention several beneficial effects of lemons, grapefruits, and oranges in the diet.

A new type of canning is said to have been discovered that does not injure the vitamin C content. By this process vegetables are submerged in slightly salty water until the oxygen of their tissues is used up. Then they are canned in such a way as to prevent the oxidation of the vitamin.

SOURCES OF THE "SUNSHINE" VITAMIN





Why is vitamin D referred to as the "sunshine" vitamin?

Vitamin C is essential to nutrition. If, for several weeks or months, a person eats foods that are entirely lacking in vitamin C, he usually suffers an attack of scurvy. His ankles and legs become swollen, bloodshot areas appear in the skin, his gums bleed, and he grows pale and weak. The harmful effects of this disease make us realize how important it is that plenty of vitamin C be included in our diet.

"Bottled sunshine"—vitamin D. Vitamin D differs from the others discussed thus far in that it is not found in much of the food we

ordinarily eat. Its real source is sunlight, and it is sometimes called the sunshine vitamin. Use of the very short ultra-violet rays of sunlight seems to produce the same healthful effect as the vitamin. Many people suffer because vitamin D is found in few foods. Among children who do not secure sufficient quantities of vitamin D a bone disease called rickets is common. This disease brings about a curvature of the bones and an enlargement of the wrists and ankles. In itself it seldom causes death, but it often makes the victim susceptible to other diseases that are fatal.

SOURCES OF VITAMIN E

Such food products as wheat, beef, lettuce, peanuts, and palm oil contain an abundance of vitamin E. What is the value of this important vitamin?

Vitamin D is the one vitamin, probably, that we need exert ourselves to secure, since the others are usually present in sufficient quantities in our food. It is found in fish, egg yolk, butter, and most abundantly in cod-liver and halibut-liver oil. Certain individuals, especially some of those who spend much of their time indoors, should take cod-liver oil or halibut-liver oil at necessary intervals.

The vitamin allied with reproduction — vitamin E. Vitamin E seems quite closely associated with the reproductive process. Experiments upon rats have shown that, even when they are fed all the other vitamins in a healthful diet, they are sterile unless vitamin E is provided. This vitamin occurs in lettuce, in lean meat, and in certain oils, such as cottonseed oil, wheat oil, palm oil, and peanut oil.

The vitamin that prevents pellagra — vitamin G. People who exist upon a monotonous diet, with little consideration for balance of diet, are most likely to suffer from a lack of vitamin G. A continuous diet of meat, meal, and molasses, for instance, or a diet of high protein and carbohydrate content, with few fresh vegetables included, is very conducive to the development of pellagra. In this disease the digestive tract becomes disturbed and the mouth and tongue become sore. Diarrhea (dī′ȧ-rē′ȧ) and a bronzing of the exposed portions of the skin also occur. Pellagra can be prevented by the inclusion of fresh vegetables, eggs, lean meats, and milk in the diet.

Scientific Weight Building and Reducing

Experimentation with Calories frequently shows that people who are underweight may approach normal weight by following a diet that contains a certain number of Calories. We find, however, that some people cannot bring their weights up to the standards set by weight tables based upon averages. They possess definite inherent family characteristics that prevent them from gaining. Whenever they eat foods that would ordinarily be assimilated, these foods are excreted instead of being stored in the form of fat. Thus if they attempt to add weight, their excretory organs may be overworked.

Overweight is frequently brought about by two causes over which we have control: lack of exercise and the consuming of excessive quantities of food. Hunger can be avoided under a reducing diet by the use of bulky foods of low caloric value, such as fruits and leafy vegetables.

Problem 4. How do living machines transform foods into actual sources of energy?

The carburetor of an automobile performs the function of vaporizing gasoline and mixing it with air. Thus the fuel is prepared for use before it enters the cylinders, where it is transformed into energy.

DIGESTION IN ANIMALS

The digestive tract of a living machine performs a function somewhat similar to that of a carburetor on an engine. Most of the food eaten by animals is insoluble and consequently cannot pass, by the process of osmosis, through the walls of the digestive system into the blood. Therefore it must be digested or made soluble before it can pass into the blood. Once absorbed, it is readily carried by the blood to all the cells of the body, where it is burned or oxidized and converted into energy. The function of the digestive system, then, is to convert food into a usable form.

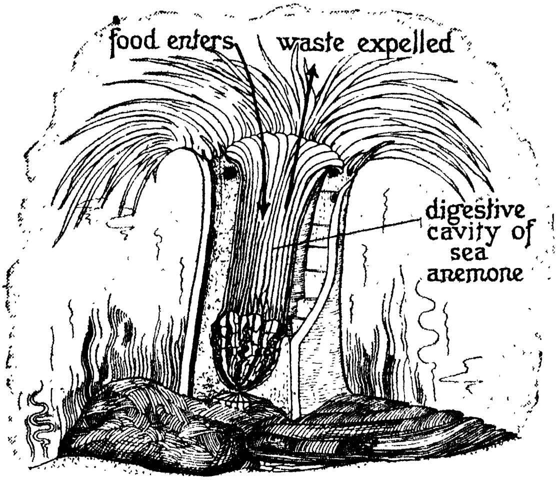
INSPECTING THE MACHINERY OF DIGESTION

Before we consider the important process of digestion, we should study the parts of the body involved in its performance. In most animals these parts are a *mouth* and a *digestive cavity.*

The simple digestive cavity of the sea anemone. In lower forms of life the digestive cavity is very simple, as shown by the digestive tract of the sea anemone. The whole body of this creature is little more than a double-walled sac with an opening at one end, which may be considered a mouth. The mouth is surrounded by waving tentacles that look somewhat like the petals of a flower. These tentacles contain tiny hairs

that remain coiled until they come into contact with food. The tentacles pull the food into the crude mouth. Digestion, which takes place in the body cavity, merely consists of chang-

A SIMPLE DIGESTIVE CAVITY



The sea anemone has a very simple digestive cavity. Food is taken into the mouth by means of tentacles. The waste is expelled through the same opening.

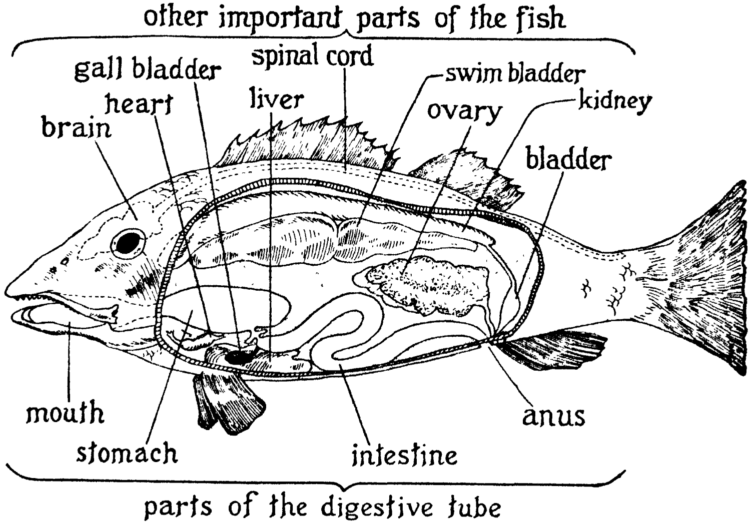
ing insoluble food to soluble. The waste is expelled through the mouth, there being no other excretory organs.

The complete digestive tubes of the fish and the frog. Higher animals, such as the fish and the frog, have a more complicated digestive cavity. This cavity is somewhat like a tube and has specialized parts, such as *mouth*, *stomach*, *intestine*, and *anus* (ā′nŭs), as shown on the following page.

In the digestive process of the fish, food is taken in through the mouth and is digested and absorbed as it passes through the stomach and intestine. Unused food is excreted through the anus. The fish also possesses a *liver*, the work of which will be explained later.

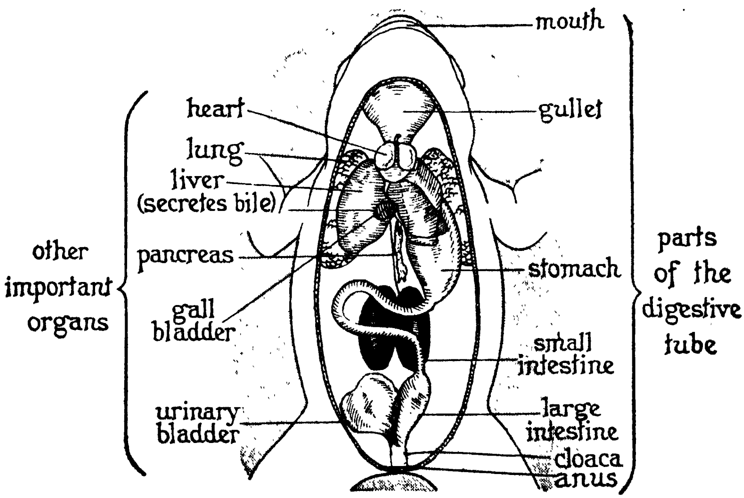
The frog possesses a still more complicated system, including a gullet, large intestines, *pancreas* (păn′krē-ăs), and *cloaca* (klō-ā′kȧ), as may be seen in the diagram on the following page.

THE FOOD TRACT OF A FISH



A higher animal, such as a fish, has a continuous digestive tube through its body. Food enters the mouth. Expulsion of unused food takes place through the anus.

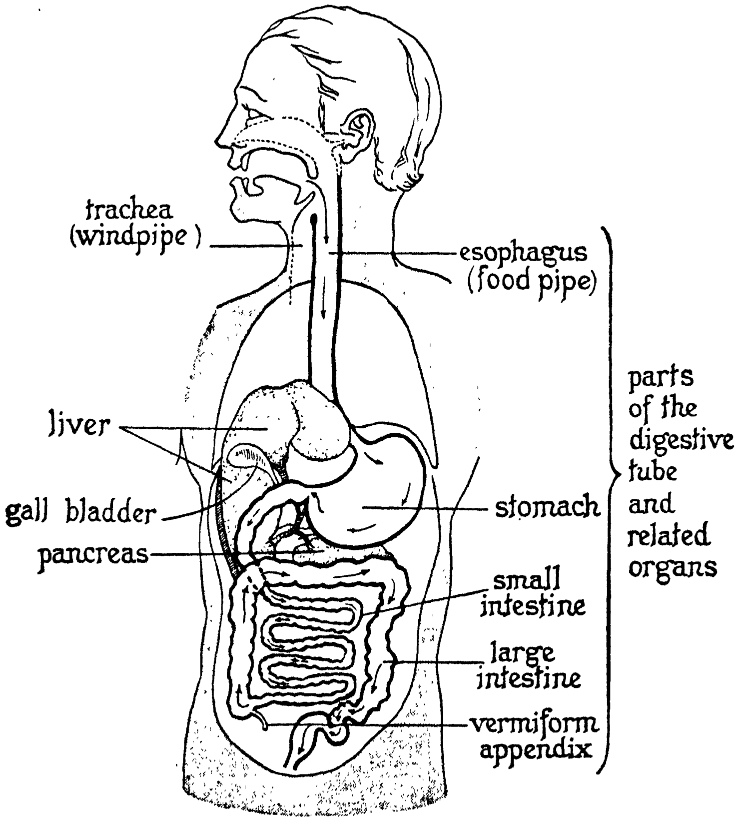
THE DIGESTIVE TUBE OF A FROG



Note that the digestive tract of the frog is more complicated than that of the fish.

The parts of man's digestive machinery. Man's organs for the performance of digestion are similar to those of the fish and the frog. His food tube is made up of a *mouth, esophagus*

THE PATHWAY OF FOOD IN MAN
THE DIGESTIVE SYSTEM



This diagram should be referred to frequently as the story of digestion is studied. Note that the liver is folded back from its normal position in order to show the gall bladder.

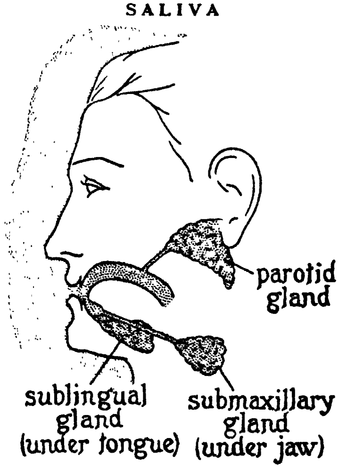
(ē-sŏf′ȧ-gŭs), *stomach, small intestine, vermiform appendix,* and *large intestine.* Like the frog, he has a *pancreas* (păn′krē-ăs) and *liver.* One of the functions of these organs is to empty digestive juices into the food tube. This tube and the organs

that manufacture and secrete digestive juices comprise the *digestive system.* The operation of this system is similar in all the higher animals.

The Part That the Mouth Plays in the Digestive Process

The *mouth* performs two chief functions in the process of digestion. Here food, through chewing, is *masticated* (măs′tĭ-kāt′ĕd), or broken up into small particles that can be attacked by the digestive juices. Here, too, is produced the *saliva,* the digestive juice of the mouth, which is secreted by the *parotid* (pȧ-rŏt′ĭd) glands under the ears and the *submaxillary* (sŭb-măk′sĭ-lȧ-rĭ) and *sublingual* (sŭb-lĭn′-gwȧl) glands under the jaw and tongue respectively. Although saliva consists chiefly of water, it also contains *ptyalin* (tī′ȧ-lĭn), a digestive *enzyme* (ĕn′zīm) or *ferment.* An enzyme is a substance which, in the process of digestion, makes insoluble foods soluble.

GLANDS THAT MAKE SALIVA



These glands manufacture the first digestive juice that attacks food as it travels through the alimentary canal.

Beginning of starch digestion in the mouth. Through the action of ptyalin, starch is converted into sugars[1] of different forms. Such sugars are simpler and more soluble than starch, and consequently are more readily digestible. The saliva performs its work best when the mouth is in an alkaline condition rather than in an acid condition.

The tongue an important organ in mouth digestion. It helps in the passage of food through the mouth and in swallowing by pushing the food back into the throat. Its upper surface contains the organs of taste, or *taste buds,* which are located at the base of small projections called *papillae* (pȧ-pĭl′ē).

[1]These forms are dextrin and maltose.

By means of the papillae we are made sensitive to sweet, salt, bitter, and sour tastes.

Through the act of swallowing, the partially digested starches, the soluble sugars, and the undigested proteins and fats in the mouth are carried down the *esophagus,* or the passageway to the stomach (see page 242). Besides the esophagus, another tube extends down the throat. This tube, the *windpipe,* lies to the front of the esophagus and leads to the lungs.

The Minor Rôle the Stomach Plays in the Digestive Process

The *stomach* is a continuation of the tubelike esophagus. However, it is much enlarged, especially when filled with food, and has a pouchlike appearance. As shown in the illustration on the following page, the larger end of the stomach joins the esophagus and the smaller end is separated from the small intestine by means of a valve known as the *pylorus* (pī-lō′rŭs). Wavelike contractions of muscles in the walls of the stomach rhythmically churn the food and force it downward. This muscular motion of the stomach is called *peristalsis* (pĕr′ĭ-stăl′sĭs).

Imbedded in the inner *mucous* (mū′kŭs) *wall* of the stomach are small *gastric glands* which secrete *gastric juice.* Gastric juice consists largely of an *acid* content and certain digestive enzymes, such as *pepsin* and *rennin* (rĕn′ĭn).

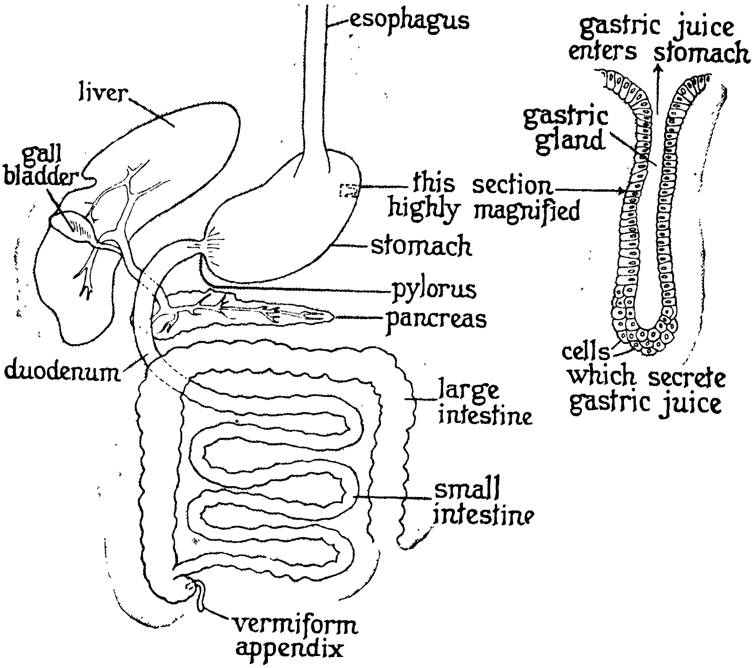
Protein digestion begins in the stomach. The gastric juice acts mainly upon proteins, converting them into such forms as *peptones* (pĕp′tōnz) and *proteoses* (prō-tē-ō′sēz). Most of the proteins, however, are not entirely converted into soluble forms in the stomach, and must pass on to the small intestine to be acted upon by other juices before the process is completed.

The gastric juice acts very little upon fats and not at all upon carbohydrates. Like proteins, fats and carbohydrates must pass on to the small intestine before they are finally converted into soluble products of digestion.

Although the stomach plays a minor rôle in the actual process of digestion, we must not underestimate its importance. It

paves the way for more complete digestion in the small intestine and converts some of the proteins into soluble forms. Because

WHERE DIGESTIVE JUICES ARE PRODUCED



The gastric glands are found in tiny pits in the walls of the stomach. Within these glands gastric juice is manufactured. Bile is produced in the liver and stored in the gall bladder; pancreatic juice is produced in the pancreas; and intestinal juice in the walls of the small intestine. The salivary glands are shown on page 243.

of its churning motion the stomach breaks down the tough fibers of certain vegetables and meats better than any other digestive organ.

THE MAJOR RÔLE THE SMALL INTESTINE PLAYS IN THE DIGESTIVE PROCESS

We shall now inspect the final mechanism of the digestive system of the great human machine. The liquid food that passes through the pyloric valve into the small intestine is known as *chyme* (kīm). Through the action of digestive

juices in the small intestine, chyme is changed into a soluble form that can be absorbed by the blood.

Where final digestion takes place — the small intestine. The *small intestine* is a coiled tube about twenty or twenty-five feet in length and about one inch in diameter. In it, three important digestive juices are at work — the *intestinal juice,* the *pancreatic* (păn′krē̇-ăt′ĭk) *juice,* and the *bile.* The intestinal juice is secreted by glands located in the lining of the small intestine, the pancreatic juice is secreted by the pancreas, and the bile by the liver. The ducts or tubes that carry the juices from the pancreas and liver unite, and empty into the small intestine not far from where it joins the stomach. By studying the illustration on the preceding page, we shall see how the small intestine, liver, and pancreas are related.

The most important digestive juice — the pancreatic. As the acid chyme enters the small intestine, it is rapidly neutralized or made slightly alkaline by the alkaline pancreatic juice. There are at least three important enzymes in this juice — *trypsin* (trĭp′sĭn) for action upon proteins, *amylopsin* (ăm′ĭ-lŏp′sĭn) for starch, and *lipase* (lĭp′ās) for fats. Trypsin continues the digestion of the partly digested proteins, reducing them to smaller *peptides* and *amino acids.* Amylopsin changes starch to *maltose,* a sugar. *Lipase* acts upon fats, converting them into *fatty acids* and *glycerin.*

An ally of pancreatic juice — the intestinal juice. The intestinal juice is also alkaline and contains two types of enzymes: one for breaking up protein substances, the other for breaking up carbohydrate substances. One of the enzymes, *erepsin,* (ē̇-rĕp′sĭn) acts on proteins, but not directly. It attacks the protein products of gastric and pancreatic digestion, changing them into a form that can be absorbed and used. Likewise, the second type (*inverting enzymes*) attacks sugars, but not directly. It acts upon such sugars as cane sugar, milk sugar, and maltose, converting them into more soluble forms. Completely digested substances, such as soluble sugars, are often called the *end products* of digestion because they are in a suitable form for absorption and use by the body.

A further ally of pancreatic juice — the bile. The most important function of bile is the stimulation of digestion. It contains no enzymes and alone has little digestive value. However, when it mixes with the pancreatic juice and the intestinal juice, it stimulates the action of enzymes so that all classes of food may be digested. Because of its alkaline nature it seems to aid directly in the breaking up and absorption of fats and in the digestion of proteins. It also prevents the putrefaction and decomposition of food in the intestine and hastens the elimination of waste products. Excess bile is stored in the *gall bladder*.

The long story of digestion briefly told. Enzymes are found in the digestive juices of the mouth, stomach, and small intestine. They convert carbohydrates, fats, and proteins into soluble products. As a result the soluble forms are readily absorbed through the walls of the small intestine into the blood stream. The food is then conveyed to all the cells of the body, where it is burned and converted into energy.

At this point it will probably be helpful to study the table on the following page for a complete picture of the long story of digestion.

The Absorption of Fuels by the Human Machine

The sole purpose of digestion is to make foods soluble. This is necessary so that, by the process of osmosis, they may pass into the blood. Let us now examine more closely the mechanism of absorption.

The "ink blotters" of the intestine — the villi. On the inside lining of the small intestine there are numerous minute finger-like projections called *villi* (vĭl′ī). It is through these villi that absorption takes place. We may think of them as functioning somewhat like ink blotters in doing their work. The walls of a villus (vĭl′ŭs) are composed of special epithelial cells that permit absorption of soluble food into the blood stream and *lymphatic system.*[1] The digested proteins and carbohydrates pass through these cells by osmosis and enter directly

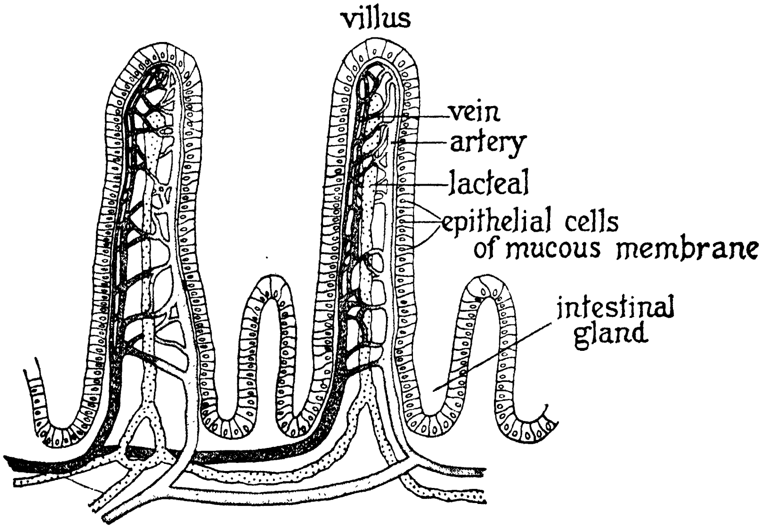
[1] **Lymphatic system — the circulatory system of the lymph.**

Summary of the Digestive Process

Place of Digestion	Organ Secreting the Digestive Juice	Digestive Juice	Food Digested	Enzyme	End Product
Mouth	Salivary glands	Saliva (alkaline)	Starch	Ptyalin	Maltose
Stomach	Gastric glands	Gastric (acid)	Protein	Pepsin	Peptones, Proteoses, Peptides
			Casein in milk	Rennin	Curd
Small intestine	Pancreas	Pancreatic (alkaline)	Carbohydrate products from mouth digestion	Amylopsin	Maltose
			Protein products from stomach digestion	Trypsin	Peptides, Amino acids
			Fats	Lipase	Glycerin, Fatty acids, Soaps
	Intestinal glands	Intestinal (alkaline)	Carbohydrate products	Inverting enzymes	Glucose + fructose, Glucose + galactose, Glucose
			Protein products	Erepsin	Peptides, Amino acids
	Liver	Bile (alkaline)	Aids in the digestion and absorption of fats	....	....

into the blood stream. The digested fats, however, pass into the *lacteals* (lăk′tē-ălz)[1] of the lymphatic system. A fluid called *lymph* (lĭmf) fills the spaces between the epithelial cells

HOW FOODS GET INTO THE BLOOD



This is a diagrammatic and greatly enlarged representation of how blood vessels in the absorbing structures (villi) of the small intestine absorb digested proteins and carbohydrates. Digested fats pass into the lacteals and lymph.

and between the absorbing blood vessels and lacteals. Through the medium of this lymph, the fats are conveyed to the lacteals. The passage of the fats from the lacteals into the blood stream will be explained later, on page 262.

The Work That the Large Intestine Performs in the Digestive Process

Although the *large intestine* is much larger in diameter than the small intestine, it is only about five feet in length. If we examine the illustration on page 245, we shall see that it has an *ascending, transverse,* and *descending* arrangement. A circular muscle at the junction of the small and large intestines

[1] **Lacteals—absorbing parts of the lymphatic system.**

holds back the food until nearly all of it is digested. Since most of the water and materials digested in the small intestine are absorbed before they reach this part of the digestive tube, the contents emptying into the large intestine are composed chiefly of indigestible substances, such as connective tissues of animal foods and cellulose of plant foods. When this residue finally reaches the lower part of the digestive tube, elimination follows.

HOW LIVING MACHINES SUCH AS PLANTS CARRY ON THE DIGESTIVE PROCESS

Plants, like animals, must carry on digestive processes, for they too are living machines and must have energy. Although they manufacture their fuel supply in the form of carbohydrates, fats, and proteins, these must be made soluble before being transported from points of storage to points of use. For example, food stored in the center of the stem or in the roots of a plant must be made soluble if it is to be used elsewhere in the plant. Only soluble substances can pass from cell to cell by the principle of osmosis.

There are no special organs of digestion in plants, but all the cells assist in the work. Digestion in them, just as in man, is brought about by enzymes. There is a special enzyme for digesting each particular type of food. Thus *diastase* (dī'ȧ-stās) assists in changing starch to the soluble sugar called *glucose*, commonly known as grape sugar.

Problem 5. How is fuel carried to points of use in living machines?

CIRCULATION IN PLANTS AND ANIMALS[1]

Before the end products of digestion can be used as fuel by either plants or animals, they must be carried to the various organs and tissues. The fluids in which they are dissolved flow through the body, bathing all the tissues. The movement of these fluids is called *circulation*.

[1]Since many teachers prefer to discuss circulation in man only, all other examples may be omitted.

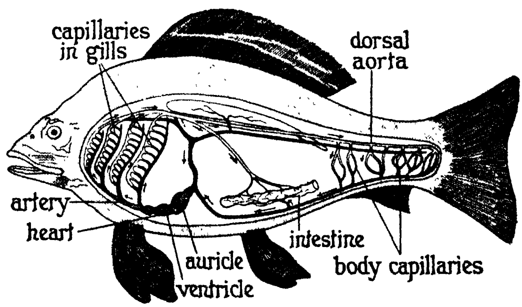
The Transportation of Fuels in Plants

In Problem 2 of this unit, we studied photosynthesis and learned how plants manufacture the world's supply of proteins, fats, and carbohydrates. In order to carry on this study, it was necessary for us to understand the structure of plants and the functions of their parts. Consequently, it is not necessary to discuss again the topic of circulation in plants. It will be sufficient to recall (1) that plants are living machines, (2) that they use three fuels (proteins, fats, and carbohydrates), and (3) that these fuels are circulated as needed to all the cells. If we do not remember these facts in sufficient detail, we should reread the section of this unit that deals with the transportation system of plants.

The Transportation of Fuels in Animals

The digestive process, as we have learned, performs the function of preparing the fuels of plants and animals for use. After proteins, fats, and carbohydrates are made soluble, they are ready to be absorbed by the body cells to be used as a source of energy when needed. Consequently, multicellular animals must have some method of conveying soluble substances to points of use. Machines made by man are equipped with fuel pumps and fuel pipes that perform this function. Higher-type animals, such as fishes, frogs, and horses, possess for this purpose a pumplike organ, called the *heart*, and tubes, called *blood vessels*, that lead to various parts of the body. Many lower-type animals, however, have less well-developed organs of circulation than those just considered.

HOW BLOOD CIRCULATES IN THE BODY OF A FISH

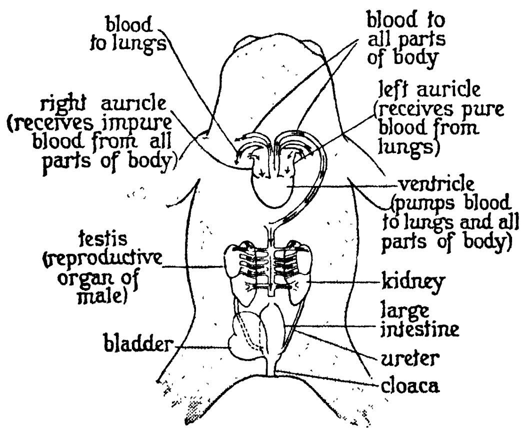


In the fish the blood passes directly to the cells after aëration.

Circulation of fuels in one-celled animals. Simple animals, such as the one-celled amoeba and Paramecium, do not, of course, have circulatory organs, but depend upon protoplasmic movement for circulation. In fact, they have no organs of any kind. They depend completely upon the simple cell to carry on all the necessary functions of life. Perhaps at this point we should reread page 76, where the circulatory process is explained and illustrated.

How fishes and frogs circulate fuels. The fish and the frog, like man, possess pumplike organs with tubelike blood vessels. In fish, as shown in the diagram on the preceding page, the pump or heart consists of two chambers called an *auricle* (ô′rĭ-k'l) and a *ventricle* (vĕn′trĭ-k'l). The arrows show that the ventricle pumps the blood to the *gills*. The blood contains, among other things, the soluble products of digestion. *Oxygen* is added to it in the gills, after which it travels through the arteries to all parts of the body. Then it returns through the veins to the auricle, or receiving part, of the heart and the entire circulation is complete.

HOW BLOOD CIRCULATES IN THE BODY OF A FROG



Note that the frog has a double circulation. The impure blood emptied into the right auricle passes into the right side of the ventricle, from which it is pumped to the lungs for purification. The purified blood containing oxygen is returned to the left auricle. From here it passes into the left side of the ventricle, from which it is pumped to all parts of the body for purposes of oxidation.

If we follow the arrows in the accompanying illustration, we shall easily understand the circulation of the frog. How does the circulation of the frog compare with that of the fish?

How Fuels Are Transported to Points of Use in the Human Body

The vehicle of transportation — the blood. Interesting as the circulatory systems in various other animals may be, we shall leave them for laboratory research and turn to the circulatory system of man. It seems logical to begin by studying the composition of *blood,* since it is the vehicle or conveyor of absorbed food products to the cells of the body. The following outline shows of what it is composed.

- Composition of the blood
  1. Plasma or fluid content
     - *a.* Water
     - *b.* Fuel content consisting of digested carbohydrates, fats, and proteins
     - *c.* Mineral salts
     - *d.* Fibrinogen (fī-brĭn′ō-jĕn)
     - *e.* Wastes
     - *f.* Certain other substances, such as antibodies and hormones (hôr′mōnz)
  2. Cellular bodies
     - *a.* Red corpuscles
     - *b.* White corpuscles
     - *c.* Blood platelets (plāt′lĕts)

In order that the function of each of these parts may be perfectly clear, we shall discuss them separately in the order listed.

1. *Plasma or Fluid Content of the Blood*

a. *Water.* Since the blood is a liquid carrying certain substances to various parts of the body, we naturally think of it as containing a high percentage of water. As a matter of fact, it is 85 per cent water and 15 per cent solids.

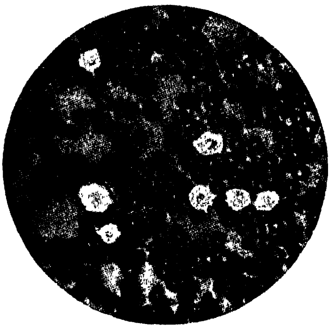
b. *Fuel content.* Of the digested fuels, the protein content is considerably higher than the fat and carbohydrate content.

c. *Mineral salts.* Certain compounds of sodium, calcium, sulfur, phosphorus, potassium, and magnesium supply the cells with the necessary mineral matter.

d. *Fibrinogen.* Fibrinogen is the fluid state of *fibrin* (fī′brĭn), which is the active agent responsible for the clotting of blood and the prevention of severe hemorrhages or

excessive loss of blood in case of injury. By the aid of minute blood platelets the fibrinogen is changed to a fibrin clot when a finger is cut or when any other such accident causes a leak in the blood stream. Removal of fibrinogen from the plasma leaves the thin liquid known as *serum*.

A DROP OF BLOOD AS VIEWED BY THE MICROSCOPE



Courtesy *Book of Knowledge* by permission of the Grolier Society

The large irregular cells are the white corpuscles. The disk-shaped cells are the red corpuscles.

THE GAS CARRIERS OF THE BLOOD—THE RED CORPUSCLES

Courtesy *Book of Knowledge* by permission of the Grolier Society

Because the red corpuscles have a scooped-out appearance on both sides, they are said to be biconcave disks.

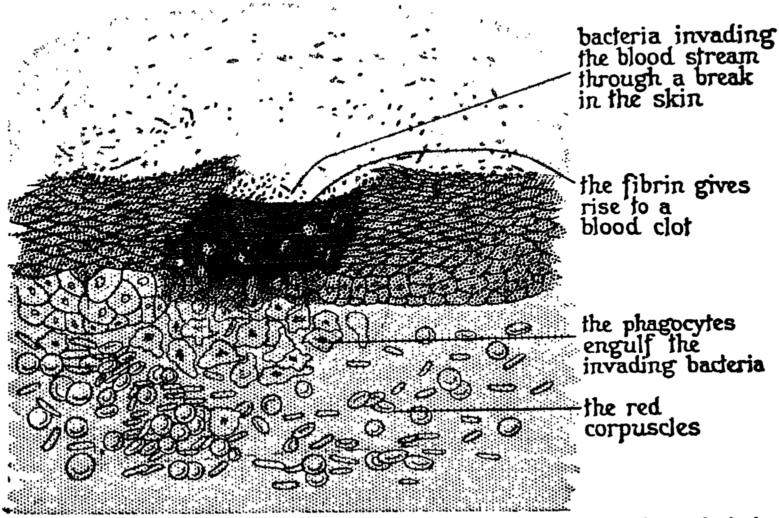
e. Wastes. The waste products in plasma are the result of fuel oxidation in the cells. Such wastes as carbon dioxide, nitrogenous urea (ū-rē′ȧ), and certain salts are picked up by the blood stream and carried to the respective organs of elimination.

f. Other substances, as antibodies and hormones. The antibodies, as we have already learned, are substances that aid in fighting diseases. We know that these substances are present even though we cannot see them with a microscope. The *hormones* activate the performance of certain organs of the body. They are manufactured by (1) glands called *ductless* or *endocrine* (ĕn′dō̆-krīn) *glands* because they have no ducts and release their secretions directly into the blood or lymph and by (2) certain other organs which will be named later. Most of the glands which we have studied, such as the liver, are called duct glands because they release their secretions through ducts or tubes.

2. *Cellular Bodies of the Blood*

a. The cells which carry oxygen. We have learned that the blood carries fuel, but it must also carry oxygen. The oxygen makes possible the slow oxidation or burning of the fuel, thus providing a living machine with energy. The red corpuscles are disklike cellular bodies that carry oxygen in the blood stream. Their ability to do this comes from the presence of a red pigment, called *haemoglobin* (hē′mŏ-glō′bĭn), which combines chemically with oxygen to form oxyhaemoglobin. Then as the blood passes the cells of the body, the oxygen is set free and absorbed by them. Red corpuscles are produced by the marrow of bones and later, when they have become old, are transformed into waste largely by the liver.

PARTS OF THE BLOOD IN ACTION



The above diagram shows how certain parts of the blood afford protection to the body when harmful bacteria enter the blood stream through a break or cut in the skin.

b. The scavengers of the blood. The white corpuscles are larger and less numerous than the red corpuscles. They have the power of locomotion and behave very much like

amoebae. Some of them, called *phagocytes* (făg′ō-sīts), have the power to engulf and digest bacteria, thus protecting us against disease. Allied with the phagocytes in their attack upon bacteria are the antibodies of the blood.

c. *Blood platelets assist in the clotting of blood.* When there is a leak in the blood stream and blood reaches the air, these tiny platelets break up and, in doing so, free a substance that combines with an enzyme to change fibrinogen into fibrin. It is the strands of fibrin that produce a clot and thus prevent excessive bleeding.

The Secretion of Hormones

Chief among the ductless glands are the *adrenals* (ăd-rē′nălz), attached to the kidneys, the *thyroid* (thī′roid) and *parathyroid* (păr-ȧ-thī′roid), located in the neck, and the *pituitary* (pĭ-tū′ĭ-tȧ-rĭ), at the base of the brain.

A hormone which "peps up" the heart. The adrenal glands secrete the hormone *adrenin*, which activates the nervous system and the muscles. It strengthens the heart beat, contracts the blood vessels, and increases the blood pressure. Sometimes when the secretion is inadequate, a commercial extract, *adrenaline* (ăd-rē′năl-ĭn), is injected into the body to bring about similar effects.

The thyroid hormone a cause of goiter. The thyroid gland also secretes a substance that affects the nervous system. An oversecretion is responsible for a condition known as *exophthalmic* (ĕk′sŏf-thăl′mĭk) *goiter*, and an extreme undersecretion for *cretinism* (krē′tĭn-ĭz′m). In the cases of goiter the thyroid commonly increases in size, causing an enlargement of the neck. It is accompanied by nervousness, loss of weight, irregular heart action, and protrusion of the eyeballs. Cretinism is a mental and physical deformity.

Effect of the parathyroid hormone on the minds of children. The parathyroid gland produces a secretion or hormone that regulates the quantity of calcium salts in the tissues. The removal of this gland results in *tetany* (tĕt′ȧ-nĭ), a disease characterized by a trembling and twitching of the muscles

and by a deficiency of calcium in the blood. A child born without a parathyroid gland or with a weak one may have defective bones and teeth and a poorly developed mind. These conditions may be corrected in part by the feeding of parathyroid tissue or by the administration of a parathyroid extract.

THE EFFECT OF THE PITUITARY GLAND ON GROWTH

Underwood & Underwood

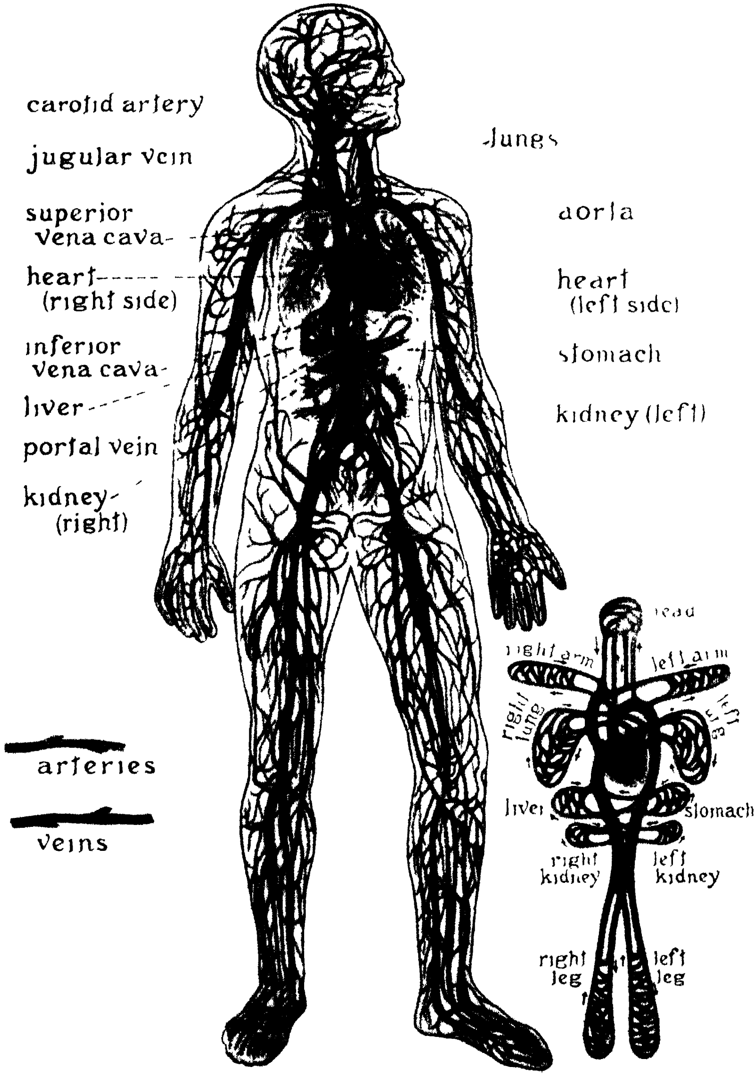
Here is a young man who is twenty-two years old, eight feet six inches tall, and still growing. The man beside him is of average height.

Defective pituitary glands possible cause of giants and dwarfs. The secretions of the pituitary gland seem to be associated with growth. This gland is separated into two lobes, an anterior and a posterior. Certain medical authorities believe that giants have abnormally large anterior lobes and that dwarfs, on the contrary, have excessively small ones.

Other organs that produce hormones. Besides the ductless glands, certain other organs, as already indicated, also produce hormones. Chief among these organs are the pancreas, the small intestine, and the reproductive organs of both male and female.

When the hormone produced by the pancreas is carried to the liver, it causes the liver to store sugar. The hormone in the small intestine, known as *secretin* (sė-krē′tĭn), is secreted by the *duodenum* (dū′ō-dē′nŭm) or the part next to the stomach, and influences the work of the pancreas. When the acid contents of the stomach begin to enter the small intestine, the blood carries secretin to the pancreas, stimulating a flow

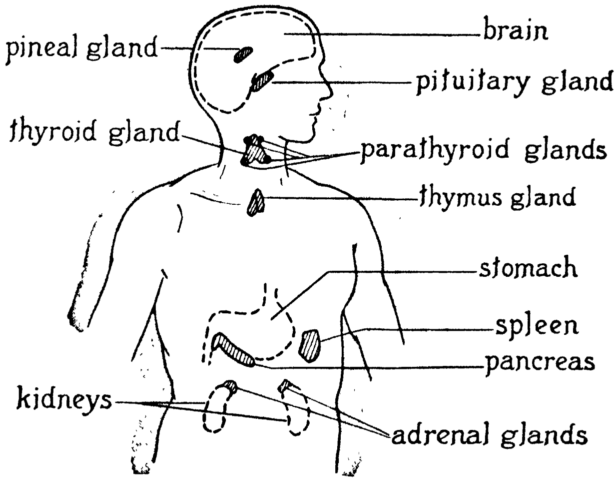
THE HUMAN CIRCULATORY SYSTEM



The larger drawing shows the distribution of the main arteries and veins in the human body. The small diagrammatic sketch at the right shows the general plan of the circulatory system. Which part of this sketch shows the systemic circulation? the pulmonary circulation? The arrows indicate the direction in which the blood flows.

of the neutralizing pancreatic juice. The hormones secreted by the reproductive organs, of course, have a direct bearing on sex characteristics and sex behavior.

SOME OF THE SOURCES OF HORMONES



The various hormones have such an effect upon the functioning of the body that they are given careful consideration in the diagnosis of disease.

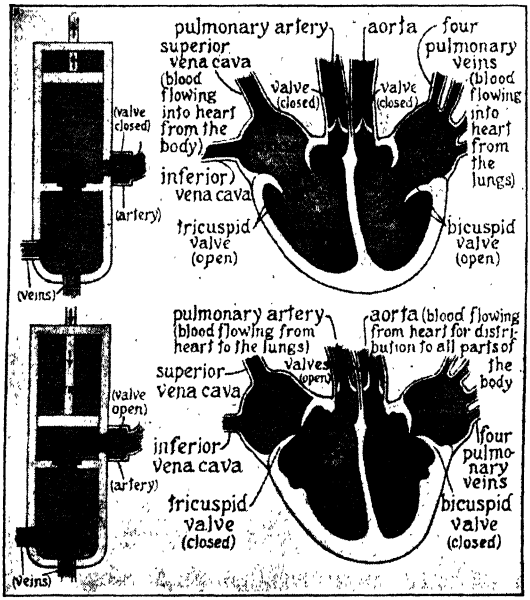
How the Blood Is Circulated throughout the Body

To form a picture of the actual circulation of the blood, it is helpful to think of the machine-like functioning of the human body. Just as gasoline is pumped through a fuel pipe line into the carburetor of an automobile, so is the blood in the human body pumped through blood vessels to the cells.

The chief parts of the circulatory system are the *heart,* the *arteries,* the *veins,* and the *capillaries* (kăp′ĭ-lā̇-rĭz). The heart acts as a pump, and the arteries, veins, and capillaries are merely tubes for carrying blood. Arteries carry the blood away from the heart, while the veins carry it to the heart. In their extremities, arteries and veins break up into small branches. The branches of the arteries are connected with the branches of the veins by small tubes called capillaries.

How the human pump operates. The human heart operates much like a mechanical pump. It is a muscular, conical-shaped organ about the size of a man's fist and lies in the middle of the chest cavity. Surrounding it is a very close-fitting membranous bag called the *pericardium* (pĕr′ĭ-kär′dĭ-ŭm).

HOW THE HUMAN HEART OPERATES



The upper and lower drawings at the right show the heart receiving blood from the body and sending it to the lungs. How does the operation of the human heart resemble that of the mechanical pumps shown at the left? (Diagrammatic)

The mechanical pump shown in the accompanying illustration has a receiving chamber and a pumping chamber, together with valves, to keep the pumped fluid traveling in the direction indicated by the arrows. The human heart operates in like manner, but it has two receiving chambers and two pumping chambers. The *auricles* receive the incoming blood and the *ventricles* pump it out. Blood enters the auricles when they are relaxed. Then, as the ventricles relax, it passes into them. A wave of muscular contractions passing from the auricles to the ventricles forces the blood outward through the arteries. *Valves* between the auricles and ventricles and outside the ventricles help to keep the blood from flowing backward.

Tracing the blood through the lungs and all parts of the body. Incoming blood from the organs below the heart drains into a large vein called the *inferior* (meaning lower) *vena cava*

(vē′nȧ kā′vȧ). Blood from parts of the body above the heart, except that from the lungs, drains into a large vein called the *superior vena cava.* These two large veins empty into the *right auricle* of the heart. As the right ventricle relaxes, blood passes into it from the right auricle. A wave of muscular contraction next sends the blood through the *pulmonary* (pŭl′mȯ-nā̇-rĭ) *artery* to the lungs, where an increase in oxygen content and a decrease in carbon-dioxide content take place. The *tricuspid valve* between the right auricle and the *right ventricle* keeps the blood from passing back into the right auricle when the ventricle contracts. Four *pulmonary veins* now carry the blood from the lungs back to the *left auricle.* From here it passes through the *mitral* (mī′trăl) or *bicuspid valve* into the *left ventricle.* A wave of muscular contraction now sends it into the large artery called the *aorta* (ā-ôr′tȧ), which distributes it through branching vessels to all parts of the body. From the branches of the arteries it passes through the capillaries to the *veins,* where it starts back to the heart. It is helped along in its course by the pressure of the muscles during exercise. Valves in the veins help to keep it flowing in the right direction.

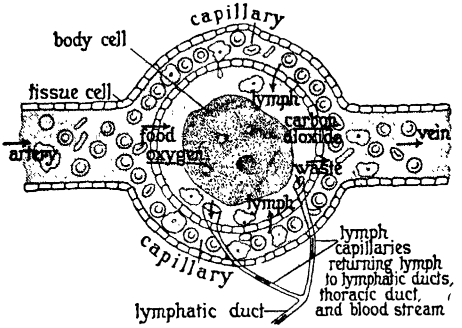
The flow of blood to and from the lungs is called the *pulmonary circulation,* and that to and from all parts of the body the *systemic* (sĭs-tĕm′ĭk) *circulation.* The systemic circulation, of course, is more extensive than the pulmonary. The illustration on page 258 shows both circulations.

How the Human "Gears" Operate in an Oil-like Bath—The Lymph

If we were to inspect the gear case of a man-made machine, we should find numerous gears and cogs immersed in an oil bath. In a somewhat similar manner the cells of the body are immersed in a tissue fluid which fills the intercellular spaces. This fluid, called *lymph,* performs different functions, however, from those of the lubricating oil of a man-made machine. It is made up partly of water and soluble food products in the blood that diffuse through the walls of the blood vessels into the intercellular spaces. It also contains white corpuscles

that escape through the walls of the blood vessels and various waste products that are thrown off by the cells. We may say, then, that lymph differs chiefly from blood in that it is a colorless fluid lacking red corpuscles and having a higher waste content.

MEDIUM OF EXCHANGE BETWEEN CELLS AND BLOOD VESSELS

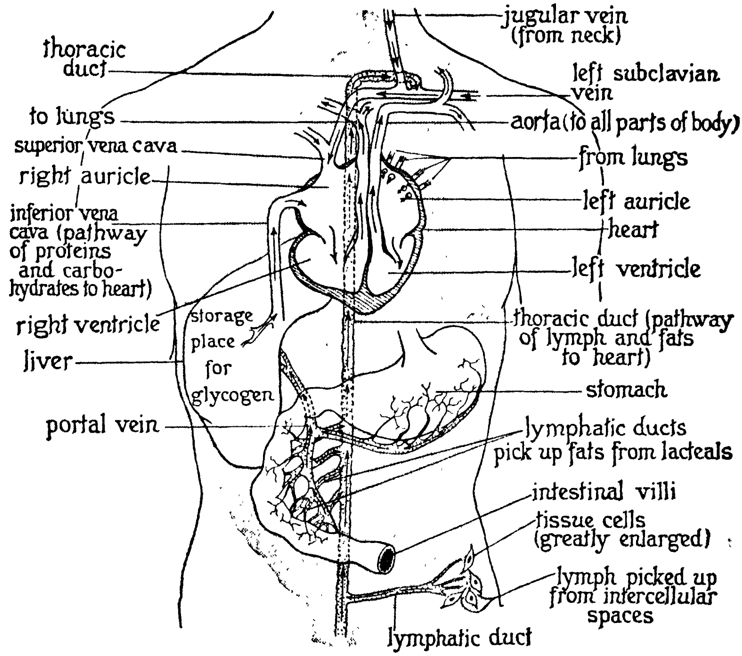


Explain how the lymph gets out of the blood vessels and back into them. (Diagrammatic)

How fats get into the lymph. Just as the oil in the crank case of an automobile is in continuous circulation, so also is the lymph. Small lymph capillaries arise in the intercellular spaces. These drain into larger vessels that unite to form two large ducts that empty the lymph into the venous system near the heart. The large duct on the right side of the body drains the lymph from the right side of the head and chest and from the right arm. The larger duct on the left side, called the *thoracic* (thō-răs′ĭk) *duct,* drains the lymph from the left arm, from the left side of the head and chest, and from the abdomen and legs. It is through the thoracic duct that fats absorbed by the lacteals pass into the blood stream. We recall that in our study of digestion we learned that lacteals in the walls of the small intestine absorb fats and turn them into the lymph stream. There are valves in the larger lymph vessels, and these, together with the squeezing effect resulting from the contraction of the skeletal muscles, help to keep the lymph in circulation.

Bacteria traps — lymph nodes. The lymph vessels contain many expanded saclike parts called *lymph nodes.* These nodes are fibrous in structure, and consequently strain out or catch many bacteria and white corpuscles as the stream moves along. The white corpuscles multiply and fight or destroy the bacteria, thus counteracting their harmful effects.

THE MOVEMENT OF THE LYMPH



This is a diagrammatic representation of the relation of the lymphatic vessels to the blood vessels. Follow the arrows as you read the story in the text.

Exchanging food products and oxygen for wastes. The main function of the lymph is to act as a medium for the exchange of food, oxygen, and waste products between the blood and the cells. Food products and oxygen are absorbed from the surrounding lymph by cells. Then, as the food products are burned or oxidized by the cells, the waste products of combustion are taken up by the lymph and turned back into the blood stream.

The importance of the circulation of the blood to the liver. Blood collected from the small intestine, stomach, pancreas, and spleen goes by way of the portal vein to the liver. Thus the circulation of blood to the liver is called the *portal circulation.* In addition to secreting bile for the digestive process,

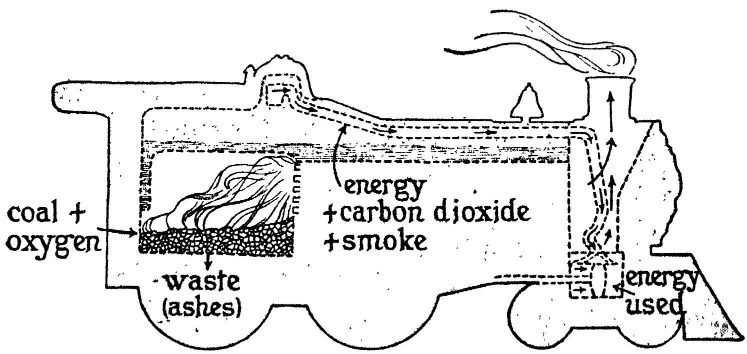
the liver removes certain wastes from the blood and acts as a storehouse for food. It acts upon excess glucose, a sugar, changing it to a storage form, *glycogen* (glī′kô-jĕn). It also extracts carbon, hydrogen, and oxygen from excess protein and converts them into glycogen. The remaining substances in the protein are converted into urea, which goes back into the blood and is extracted by the kidneys.

If there is a deficiency of food in the blood, this deficiency is supplied by the liver from its stored glycogen. Thus the liver helps to balance the food materials in the blood. It also helps to rid the blood of broken-down red corpuscles.

Problem 6. How is oxygen supplied to the cells and how is carbon dioxide removed?

The energy of man-made machines comes from two factors—*fuel* and *oxygen*. The oxidation of the fuel produces energy. The purpose of this problem is to present the method of supplying oxygen to the cells of living machines. We shall find it helpful to study first the production of heat in a locomotive.

THE OXIDATION OF FUEL IN A LOCOMOTIVE



How do the processes involved in the production and use of energy in this machine compare with those employed in developing and using energy in the human machine?

The oxygen in a locomotive enters through a draft in the fire box. It burns or oxidizes the coal and thus results indirectly in the production of steam. During the process of oxidation

smoke and ashes accumulate as waste products. This fact may be represented by the formula:

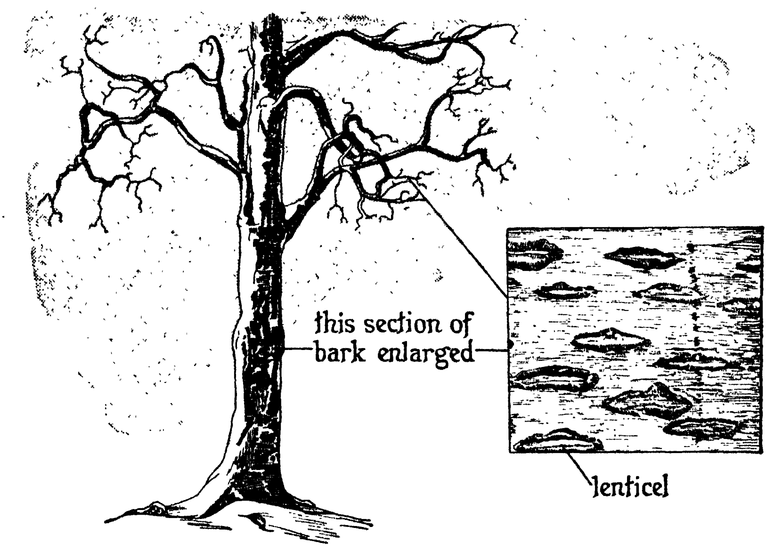
Coal+Oxygen=Energy+Wastes (Carbon dioxide, Smoke, and Ashes)

That living cells secure their energy in much the same manner may be seen by comparing the following formula with the above:

Food+Oxygen=Energy+Wastes (Carbon dioxide, Urea, and Organic Salts)

The process by which cells obtain energy through the oxidation of foods is called *respiration.* Thus oxygen is supplied to the cells, and wastes, such as carbon dioxide, are removed. The act of taking in air laden with oxygen and of giving off air laden with carbon dioxide is called *breathing.*

BREATHING PORES OR LENTICELS IN THE BARK OF A TREE



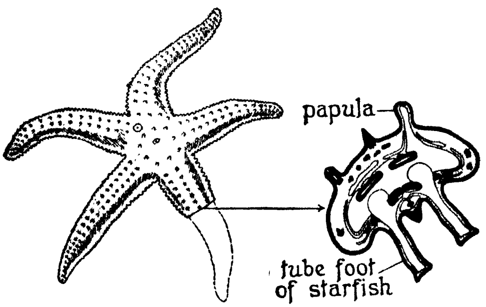
Even though a tree has no leaves and appears more or less lifeless during the winter, it lives on, breathing by means of the lenticels in the bark on its branches and trunk.

How plants secure oxygen. The roots, stems, and leaves of plants contain small openings or pores through which the plants

carry on respiration. In leaves, as we have learned, the openings are known as stomata and in the bark of woody plants, as lenticels. Through such openings as these the oxygen flows in and fills spaces around the cells. It then oxidizes the food stored in the near-by cells, such as starches or sugars and thus produces energy for the maintenance of life. In the oxidizing process, carbon dioxide is liberated as a waste product. Therefore in respiration plants, like animals, take in oxygen and give off carbon dioxide. Perhaps the best breathing organs in plants are the leaves, but the fact that many plants live through the winter without leaves shows that they also breathe through the numerous openings in their stems and roots. The respiration proceeds day and night, and summer and winter, so long as the plants live.

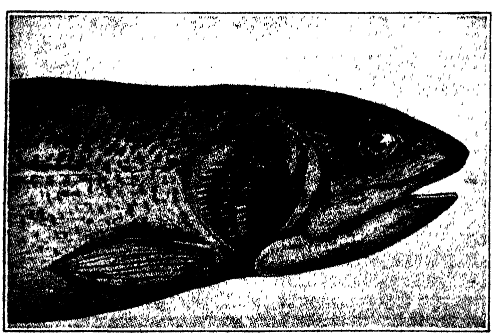
How animals secure oxygen. Single-celled animals, such as the common Paramecium, secure oxygen by absorption through the cell wall. Multicellular forms of aquatic life, such as the starfish, often breathe by means of tiny baglike projections on the body called *papulae,* one of which is shown in the upper illustra-

THE BREATHING APPARATUS OF THE STARFISH



The above drawing shows a starfish and one of the small sections through which it breathes.

THE GILLS OF THE FISH



Courtesy *New Wonder World*

This picture shows the uncovered gills of a fish. As water passes from the mouth over these parts, they take oxygen from the water and give off carbon dioxide.

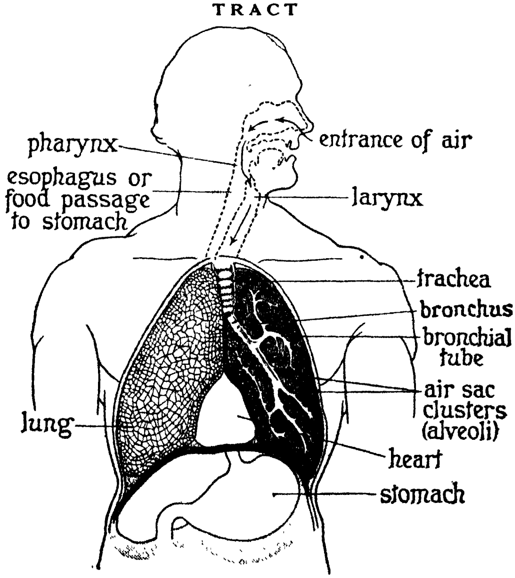
tion. Still higher forms of aquatic life, such as fish, squids, and clams, breathe by means of *gills*, shown in the lower illustration on the preceding page.

Most land animals breathe by means of baglike or bellows-like structures called *lungs*. A frog, for example, has two such lungs, as also has man and all other higher forms of life. The expansion and contraction of these structures regulate the intake and expulsion of air. From this movement of air the lungs absorb oxygen and release carbon dioxide.

How Man Secures His Oxygen

The parts of our breathing apparatus. We may think of the human respiratory (rē-spīr′ȧ-tō-rĭ) tract as a tube to which are attached two baglike tanks. Air normally enters the tract through the nostrils, but may enter through the mouth. In fact, mouth breathing, though not normal, must be resorted to when enlarged *adenoids* (ăd′ē-noidz) are present. The air passes by way of the *pharynx* (făr′ĭnks), or back of the throat, into the *larynx* (lăr′ĭnks). This organ is the voice box, commonly called "Adam's apple," and is made up of very thick cartilage. It is by means of this box that we talk and sing. The accompanying illustration shows all these parts.

THE PARTS OF MAN'S RESPIRATORY TRACT



Note the continuous passageway by means of which during respiration air travels from the nostrils to the alveoli.

Note that the respiratory tract lies ventral to, or in front of, the food tube. We must remember that we have two tubes extending down the throat—the esophagus, which conducts food to the stomach, and the windpipe, or *trachea* (trā′kē-ȧ), which conducts air to the lungs. A slitlike opening into the larynx is called the *glottis* (glŏt′ĭs). When we swallow food, a lidlike structure, the *epiglottis* (ĕp′ĭ-glŏt′ĭs), closes the opening into the larynx and keeps food from going down into the lungs.

The trachea, or windpipe, breaks up into two main tubes, called *bronchi* (brŏŋ′kī), one leading to each lung. The smaller subdivisions of the bronchi are called *bronchial tubes.* All of the air tubes are lined with hairlike structures called *cilia* (sĭl′ĭ-ȧ), which are in constant lashing motion. It is the function of these cilia to help remove dust and harmful substances from the respiratory tract. The bronchial tubes end in pouchlike air sacs called *alveoli* (ăl-vē′ō-lī). Covering each alveolus are numerous capillaries. It is through these that the blood takes oxygen from the air and gives off carbon dioxide.

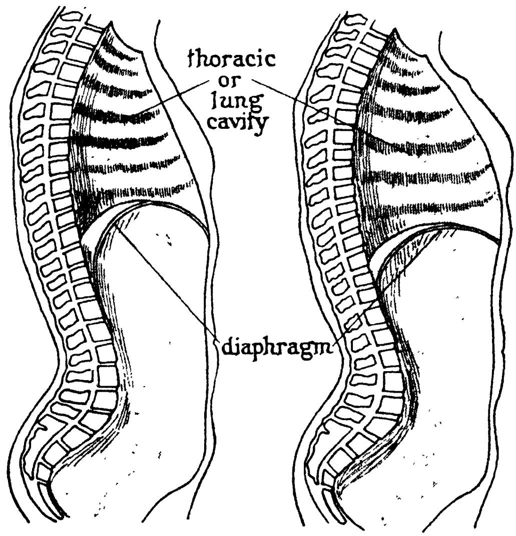
The lungs are inclosed in an elastic, membranous sac called the *pleura* (plōō′rȧ). A pleural liquid prevents friction between the lungs and wall of the chest as the lungs are inflated and deflated. They are inflated during the process of *inspiration* when air entering the nostrils passes on to the alveoli. They are deflated in the process of *expiration* when the air is forced out of the alveoli. Inspiration and expiration together are known as *respiration.*

Let us now look at the illustration on the preceding page and see whether we can trace the movement of air during the complete process of respiration.

How our breathing apparatus operates. We breathe by means of muscles attached to the ribs and an elastic muscular floor of the pleural cavity known as the *diaphragm* (dī′ȧ-frăm). This floor divides the body cavity into two parts—the *thoracic* (thō-răs′ĭk) or *pleural cavity* above, containing the heart and the complete respiratory tract, and the *abdominal* or *peritoneal* (pĕr′ĭ-tō-nē′ăl) *cavity* below, containing such organs as the stomach, intestines, liver, pancreas, and kidneys.

As the *diaphragm*, or elastic muscular floor of the chest, contracts, it tends to flatten so that it is less arched than it was before. This action, together with a contraction or pulling upward and outward of the muscles of the ribs, increases the size of the chest cavity and permits inhalation of air. Next the diaphragm and the muscles attached to the ribs relax, and the ribs settle to a lower position, forcing air from the lungs and bringing about the process of exhalation.

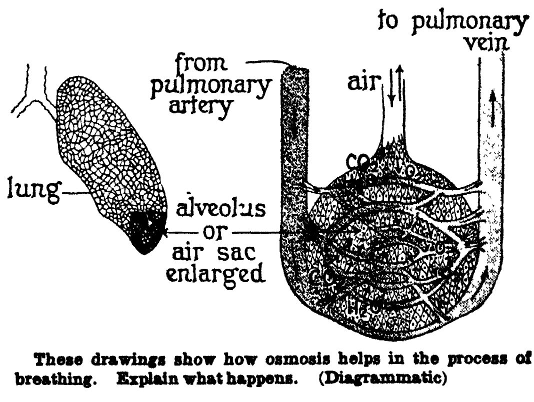
HOW THE DIAPHRAGM AIDS IN BREATHING



During an inhalation the diaphragm tends to flatten, thereby increasing the size of the chest cavity. During an exhalation the diaphragm becomes arched.

Correct breathing consists of (1) an upward and sideward motion of the ribs when air is inhaled, and (2) a contraction of the abdominal or waist muscles, causing an inward movement of the waist line when air is exhaled from the lungs.

THE TRADE OF OXYGEN FOR CARBON DIOXIDE



These drawings show how osmosis helps in the process of breathing. Explain what happens. (Diagrammatic)

Comparison of inspired and expired air. We must not think that any great change takes place in the air while it is in the lungs. In other words, we do not breathe in pure oxygen and breathe out pure carbon dioxide. In fact, the change in the composition of expired air from that of inspired air is very slight, as we can see from the following table:

Gases in the Air	Approximate Composition of Inspired Air	Approximate Composition of Expired Air
Oxygen	20.00 per cent	16.00 per cent
Nitrogen	79.00 per cent	79.00 per cent
Carbon dioxide	.04 per cent	4.00 per cent

Note that these figures do not make a total of 100 per cent. Traces of other gases, water vapor, and organic impurities also enter into the composition of the air.

Problem 7. How are wastes removed from living machines?

As we examined the picture on page 264, we found that a locomotive burns or oxidizes coal to produce heat or energy and forms certain wastes. These wastes, chiefly smoke and ashes, must be removed so that it may continue its work.

EXCRETION IN PLANTS AND ANIMALS

Like the locomotive, all living machines carry on oxidation and consequently form certain wastes that must be removed. They take in oxygen which oxidizes food, forming energy and releasing wastes, including carbon dioxide. These processes, of course, are less noticeable in plants than in animals.

How plants throw off wastes. Plants have no lungs, of course, with which to carry on respiration but admit air through openings in the leaves, stems, and roots. The oxygen admitted in this manner oxidizes or burns the food materials, such as sugars and starches, stored in the cells. In the process of oxidation energy is formed for the maintenance of life and, in addition, certain waste products, chief of which is carbon

dioxide. Therefore in the process of breathing and subsequently in the process of oxidation, plants, just as animals, take in oxygen and give off carbon dioxide. The intake of oxygen and outgo of carbon dioxide, however, is so small in comparison with the reverse movements associated with photosynthesis that we commonly think of plants as taking in only carbon dioxide and giving off only oxygen.

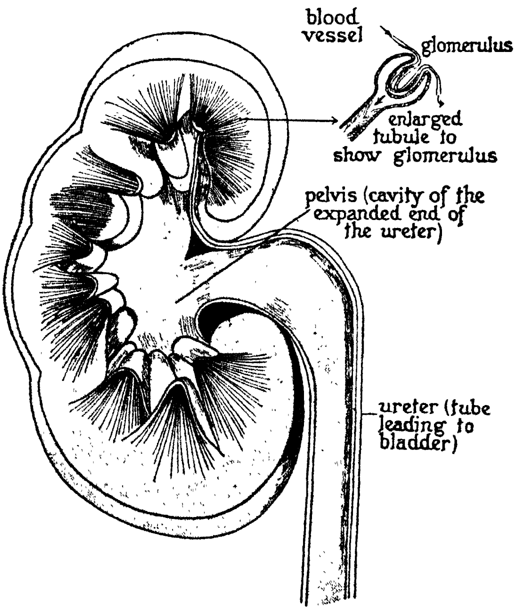
How the Human Machine Eliminates Wastes

The four chief organs for the removal of wastes in the human machine are the following:

1. *Large intestine*—eliminates unused, indigestible food, bile substances, and some nitrogenous compounds
2. *Lungs*—give off carbon dioxide and water
3. *Kidneys*—give off urea, uric-acid salts, water
4. *Skin*—passes off urea, salts, water

We have already learned how the large intestine rids the body of wastes and how the lungs give off carbon dioxide. We shall therefore turn directly to a study of the kidneys and of the skin as very important organs of excretion.

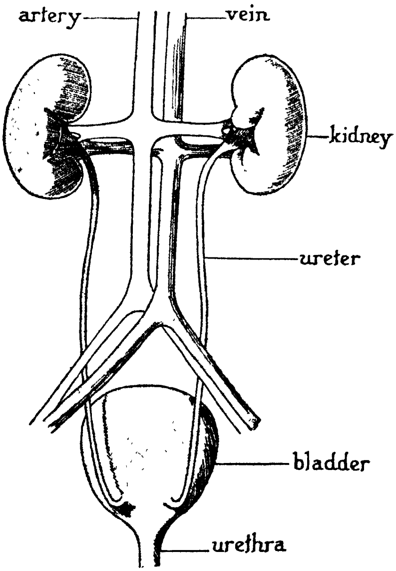
HOW WASTES ARE REMOVED FROM THE BLOOD IN THE KIDNEYS



Each kidney is made up largely of tubules, at the outer ends of which are masses of blood vessels called glomeruli. Wastes pass from the blood vessels into the tubules, on to the pelvis, and thence through the ureter to the bladder.

The structure of the kidneys. The kidneys are two bean-shaped organs lying in the back or dorsal region of the body. Each has a tube called a *ureter* (ū-rē′tẽr), which conveys the secreted wastes to the *bladder*, from which they are discharged from the body. Within each kidney the ureter expands into a basin known as the *pelvis*. The relation of ureter, kidney, and bladder can be seen in the accompanying diagram.

HOW THE KIDNEY WASTES ARE EXCRETED



Wastes, extracted from the blood by the kidneys, pass by way of the ureters to the bladder, leaving by way of the urethra.

The extraction of wastes from the blood. The inner part of the kidney contains tubules which connect the pelvis, or cavity of the kidney, with the outer part of the kidney. Each tubule is expanded at its outer end into a sac which is filled with a mass of tiny blood vessels. Such a mass is called a *glomerulus* (glǒ-mĕr′o͞o-lŭs; plural, glǒ-mĕr′o͞o-lī). As the blood flows through the glomeruli, the wastes pass by osmosis into the sacs and from there to the tubules which carry them to the pelvis. These wastes are chiefly water, urea (nitrogenous waste), salts, and some other nitrogenous substances, such as uric acid. All of these wastes, and the water containing them, are called *urine* (ū′rĭn). Ninety-six per cent of urine is water.

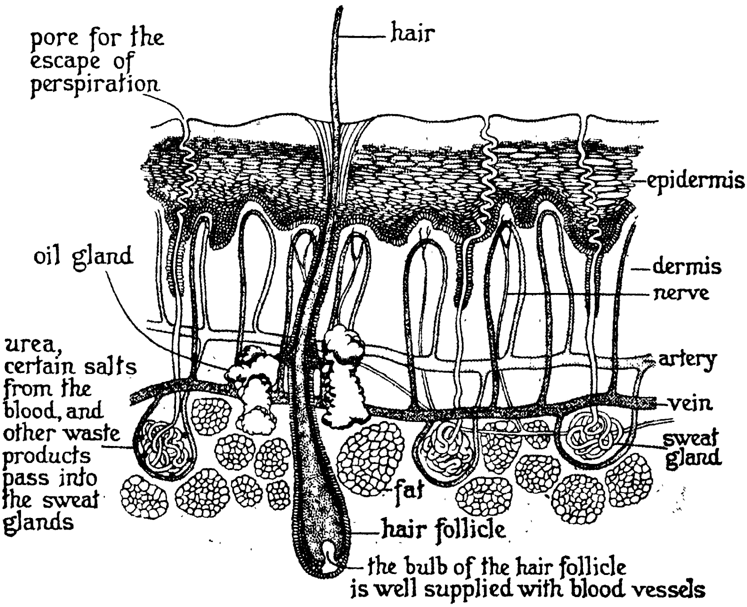
We may think of the kidneys as among the chief purifiers of the blood in that they remove wastes and harmful substances, such as an excess of sugar or albumen, from the system. They share with the lungs and the skin the work of keeping the right proportion of water content in the blood. It is

obvious, then, that the normal functioning of the kidneys is essential to the maintenance of good health.

How the Skin Excretes Wastes

The skin as a purifier. Since the skin spreads over so much surface, it eliminates more bodily wastes than we realize. Among these wastes are salts, urea, and carbon dioxide. The

MAN'S THERMOSTAT AND PURIFIER – THE SKIN



The text gives a full explanation of the function of the skin and its parts.

accompanying illustration shows that blood vessels in the skin come into close contact with little coiled openings known as *sweat glands.* Perspiration containing water and waste products passes by osmosis into the sweat glands. From these openings it evaporates and leaves a deposit of waste products on the surface.

The same illustration shows the nerve endings in the *dermis,* or underlayer of the skin. It is through these little

nerves that sensations of pressure, pain, and temperature are experienced.

The skin as a "thermostat." The skin of man is not only an organ of excretion, but it is also a regulator of temperature. The loss of water in the form of perspiration tends to keep the body at a constant temperature, 98.6° Fahrenheit. If the body becomes too warm, more perspiration evaporates, bringing about a cooler condition. If the body becomes too cold, the reverse takes place and the body is warmed.

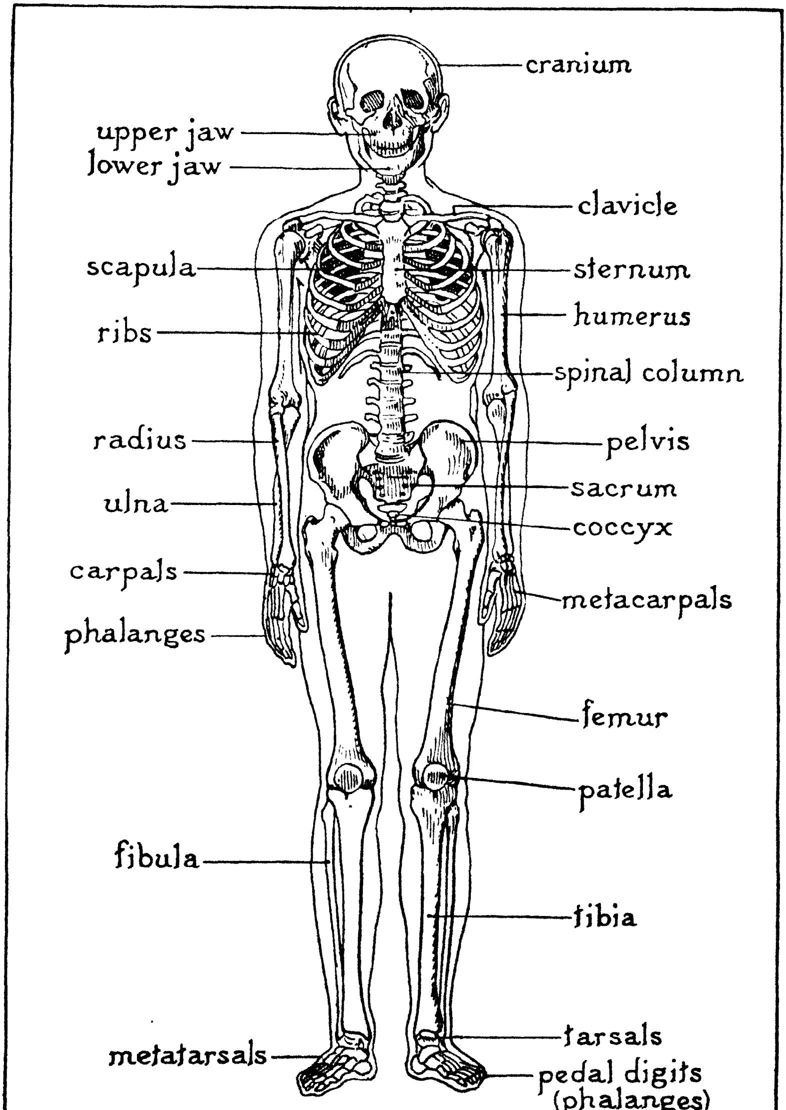
Problem 8. What use is made of energy by living machines?

THE SKELETAL AND MUSCULAR SYSTEM

This unit, thus far, has given us a picture of the production of energy by living machines. We have noted how food is oxidized or burned in the production of heat and energy. The next problem is to find out what becomes of the energy. In this regard, as in others, we shall find that living machines behave much like mechanical ones. In other words, both plants and animals consume energy in the processes of daily living much as machines do in their work. For an understanding of how this happens we shall consider the consumption of energy in the human body.

The Framework of the Human Machine and Its Relation to the Consumption of Energy

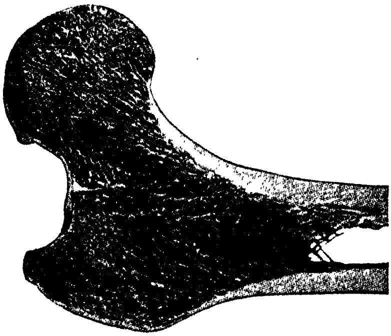
The human skeleton serves the body in a number of ways, the most important of which are: (1) to aid it in moving about, (2) to give it support, and (3) to give it protection. The long, straight bones are used largely for motion and support, and the flat ones for protection. The skeleton is often considered in two parts, the *axial* (ăk′sĭ-ăl), including the bones of the head and trunk, and the *appendicular* (ăp′ĕn-dĭk′ū-lȧr), including the bones of the arms and legs. The illustration on the following page shows the principal bones of the skeleton. As we study the shape and arrangement of these bones, we can readily see why they function so effectively.



Courtesy *Hygeia Magazine*

Structure of bones. Bones are hard in texture because two-thirds of their substance is mineral matter. As already stated, they are of various shapes. The longer bones of the body consist of hollow shafts filled with a substance composed largely of blood vessels and fat. This substance, known as *yellow marrow,* helps to nourish the bones. The ends of the bones are spongy and filled with a substance, known as *red marrow,* which forms red corpuscles for the blood. The accompanying illustration shows what the spongy end of a bone is like. The ribs and most flat bones are spongy throughout and therefore contain no yellow marrow. All bones have a close-clinging protective fibrous covering known as the *periosteum* (pĕr′ĭ-ŏs′tē̆-ŭm).

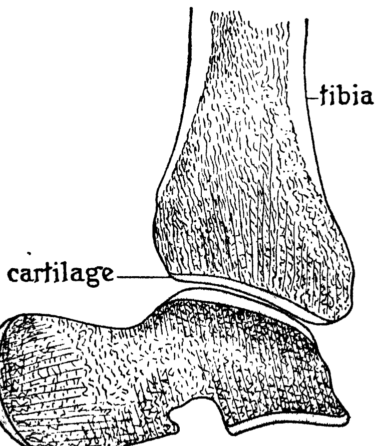
A BONE AND ITS PARTS



Courtesy *Hygeia Magazine*

This longitudinal section shows the spongy nature of the end of a long bone.

A SHOCK-ABSORBING STRUCTURE—CARTILAGE



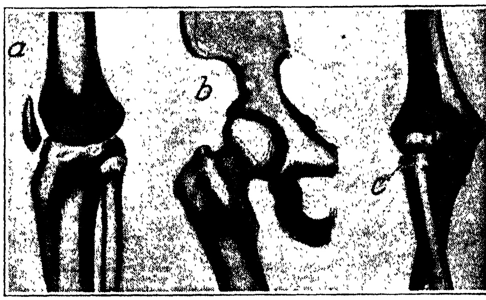
The cartilage between bones helps to protect the skeleton from jars. It is lubricated by a fluid which overcomes the effects of wear.

How the skeleton aids in motion. The skeleton is pliable because of two kinds of joints, *movable* and *elastic.* The movable joints allow one bone to move with considerable freedom upon another. Examples of movable joints are those of the elbow, knee, and shoulder. The elastic joints, which serve more as shock absorbers, are found in such places as between the bones or vertebrae of the spine and between the ribs and the sternum (breastbone).

When the skeleton is in motion, it is protected from jars by a shock-absorbing substance that covers the ends of the bones. Such a padlike substance is known as *hyaline cartilage* (hī′ȧ-lĭn kär′tĭ-lĭj). To prevent the wearing effect of friction as one bone moves upon another, cartilage is lubricated by a fluid called *synovial* (sĭ-nō′vĭ-ăl) *fluid.* Tough bands of tissue called *ligaments* hold the bones of the joints together.

Types of movable joints. There are four types of movable joints: *hinge, ball-and-socket, pivot,* and *gliding.* An example of the hinge type is the elbow, which allows motion back and forth like that of a door. The hip joint illustrates the ball-and-socket type. Here the rounded end of the *femur,* or thigh bone, fits into a cuplike hollow in the *pelvis,* or curved bones that hold the abdomen, allowing great freedom of motion in the leg. The first and second vertebrae of the spinal column illustrate the pivot joint. Here the first vertebra turns upon the second, allowing the head to turn in a rotating manner. Gliding joints in the wrists and ankles help to provide general flexibility of the hands and feet.

THREE TYPES OF JOINTS IN THE HUMAN BODY



Courtesy *World Book Encyclopedia*

The three types of joints are: (a) hinge; (b) ball-and-socket; (c) pivot. Study the drawing of the skeleton on page 275 and locate other joints of these types.

The supporting and protecting bones. The internal organs are supported and housed chiefly by the *shoulder* and *pelvic girdles,* the *spinal column,* the *sternum,* and the *ribs.* The shoulder girdle is made up of the collar bone (*clavicle*) and the shoulder blade (*scapula*) and, together with the ribs and the major part of the spine, incloses the upper part of the internal organs. The pelvic girdle is formed by the hip bones and the base of the spine. It incloses the lower internal organs.

The spinal column is made up of twenty-six bones. The upper twenty-four are separate vertebrae. The lower two, called the *sacrum* (sā′krŭm) and *coccyx* (kŏk′sĭks) respectively, are closely joined to the hip bones. (See page 275.)

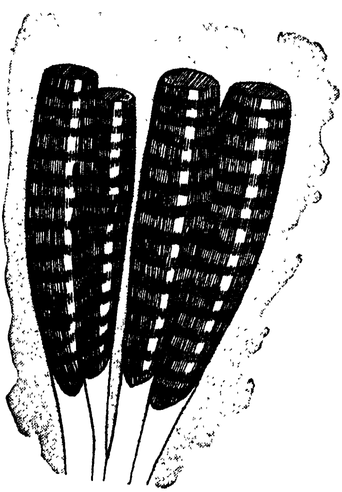
To the main vertebrae of the spinal column, twelve pairs of ribs are attached. The upper seven pairs (*true ribs*) are also attached to the breastbone, or sternum, at the front of the body. The next three pairs (*false ribs*) are attached to the ribs directly above them. The last two pairs have no attachment in front, and therefore are commonly called *floating ribs.*

The *cranium,* or skull, incloses and protects the brain.

The Muscles and Their Use of Energy in the Human Machine

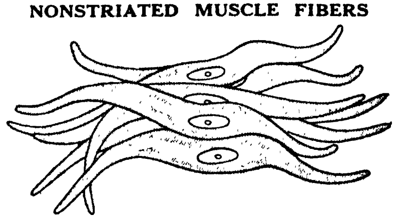
The bones of the skeleton may be compared to the wheels and other movable parts of a locomotive. Like the parts of a locomotive, they move, but not by their own power. The power in the body comes from energy delivered to muscles, whereas in the locomotive the power comes from energy delivered to the cylinder and pistons. Not all the energy of the body is consumed in muscles. It is consumed in all parts of the body, even in the brain. At this point,

STRIATED MUSCLE FIBERS



The striated muscles expand and contract through the action of the striated fibers which look like bands.

NONSTRIATED MUSCLE FIBERS



How do these muscles differ in structure and appearance from the striated muscles shown in the drawing at the left?

THE LARGEST MUSCLE IN THE BODY

Courtesy Spencer Lens Company

This powerful muscle, which is connected to the heel bone by the tendon of Achilles, is used in lifting the leg while walking and running.

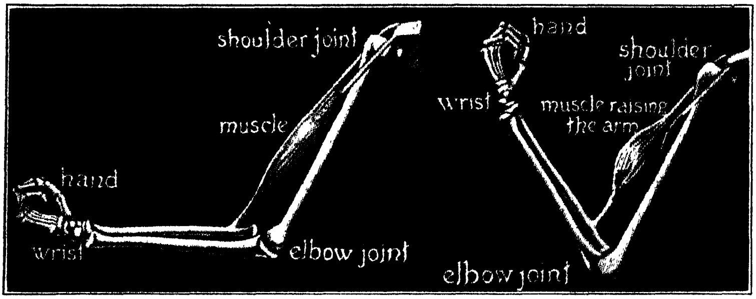
however, we shall consider only the consumption of energy by the muscles themselves.

Kinds of muscles. All muscles move under the control of the nervous system. Some of them work under conscious control and are called *voluntary,* while others work without conscious control and are called *involuntary.* The voluntary muscles move the parts of the skeleton. The involuntary muscles keep the internal organs at work.

Muscles that obey our will — voluntary muscles. The voluntary muscles are made up of bundles of threadlike fibers each of which consists of fine strands called *fibrils,* or true muscle cells. Each cell contains many nuclei. The muscular bundles are bound together by connective tissue. Some of the muscles are attached directly to the bones, but others are connected by strong flexible bundles of fibrous tissue known as *tendons.* When a small piece of muscle is examined under the microscope, it can be seen that the fibers have fine stripes running lengthwise and small bands crossing them. Hence voluntary muscles are called *striped* or *striated* (strī′āt-ĕd), as shown in the drawing on the preceding page.

Most of the voluntary muscles exist in pairs and tend to oppose each other in their motion. Thus muscles that bend the limbs oppose muscles that straighten the limbs. Those that bend the limbs are called *flexors,* and those that straighten them, *extensors.* A good example of flexors and extensors is found in the arm. The *biceps,* a flexor muscle on the inside of the arm, bends it at the elbow. The *triceps,* an extensor muscle on the outside of the arm, straightens it.

HOW THE BICEPS MUSCLE RAISES THE ARM



Courtesy *Book of Popular Science* by permission of the Grolier Society

When the biceps muscle contracts, the arm is drawn up. Extend your right arm. Grasp the biceps muscle and feel it shorten and thicken as the forearm is raised.

Muscles that work in a circular manner are called *sphincter* (sfĭnk′tẽr) *muscles.* Many of these muscles are found around the mouth and eyes and help to account for facial expressions.

Muscles we do not command — involuntary muscles. Most of the involuntary muscles are made up of smooth nonstriated fibers bound together into bundles. These fibers are composed of spindle-shaped contractile cells, each of which has a nucleus. There are certain exceptions, however, to the general structure of involuntary muscles. The *cardiac* muscle of the heart, for example, resembles a voluntary muscle in that it is striated. It resembles an involuntary muscle in that each cell has a single nucleus.

Problem 9. How may living machines be kept in efficient operation?

A certain merchant claimed that he kept an electric fan at work over a period of twenty years. He attributed its long life to the fact that at regular intervals he cleaned, oiled, and adjusted it. Likewise, the care that a person gives to his own body has much to do with its efficiency and with the length of time it remains in good working order. The application of care to the human body is known as *hygiene.* Hygiene has such a great bearing upon maintenance and preservation of health that we cannot afford to overlook its importance.

HYGIENE AND SANITATION

Every thinking individual recognizes the fact that, if he wishes to live long and efficiently, he should begin early in life to study and apply sensible hygienic practices. It is impossible to discuss here all the practices one should follow, but it is hoped the various suggestions will stimulate an interest in personal hygiene and arouse a desire for additional information.

Keeping the Digestive System in Health

The diet. One of the chief factors in health is proper food. It is essential that the diet be adjusted to the needs of the body. For example, an individual having a tendency to high acidity would be foolish to indulge in such foods as tough, fibrous meats, cranberries, strawberries, spices, and rhubarb, since they would only increase the acid content of the stomach. Likewise, laxative foods, such as baked apples, prunes, berries, fibrous vegetables, and bran, may be ideal for one individual but too rough and irritating to the sensitive intestinal tract of another. Then, too, overeating and the eating of food between meals are not conducive to good health because they throw such a heavy strain upon the digestive system that it may not function properly.

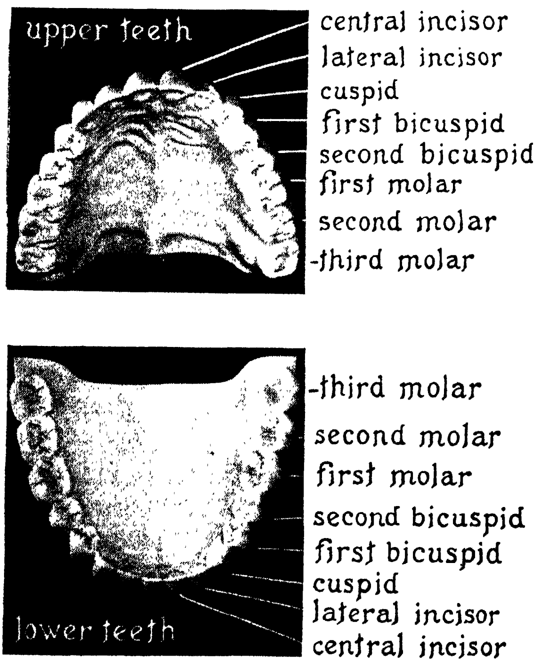
Getting rid of the wastes. Obviously, one of the most important hygienic practices is the proper elimination of wastes. When intestinal residue accumulates in the colon (large intestine) and is not promptly eliminated, harmful decay or putrefaction begins. Billions of bacteria are at work in the colon, and being alive they excrete wastes. These wastes, or toxins, are absorbed by the body and soon begin to impair the functioning of such organs as the brain, lungs, and kidneys. The absorption of toxins or poisons within the body in this manner is called *autointoxication.*

It is considered essential to good health that the lower part of the colon be emptied one or more times a day. There are, however, a few exceptions to this rule, for some people are able to maintain their health even though they evacuate only once every two or three days. The secret of curing constipation

lies in the cause. The condition of each individual presents a specific problem and consequently requires a specific remedy. There are certain common needs, however, met by the following rules:

1. The diet should be so adjusted to the individual that good digestion and proper laxative qualities are maintained.
2. Proper exercise should be taken so as to keep the muscles from becoming sluggish.
3. Six or more glasses of water should be drunk daily to maintain a proper laxative consistency in the waste materials.
4. A definite time should be established for evacuation every day, so as to promote intestinal rhythm.

MAN'S PERMANENT TEETH



Century Photos

Man and most of the animals have two sets of teeth, an early or temporary set and an adult or permanent set. These pictures show the teeth in the permanent set.

The relation of teeth to health. Teeth are related to health in two principal ways:

First, they must be properly used. Slow mastication or chewing of food is one of the first and most important steps in the digestive process. This is necessary if the food is to be broken into particles sufficiently small to be acted upon by the digestive juices. Also, slow mastication gives food more time in the mouth for action of the saliva to occur.

Second, the teeth, in themselves, must be kept healthy. If decay, pus pockets, and abscesses form in the teeth, toxic products (bacterial excretions) will be carried to other parts of the body. These products may cause serious injury to such parts as the delicate valves of the heart. Careful people always have their teeth examined and cleaned twice a year.

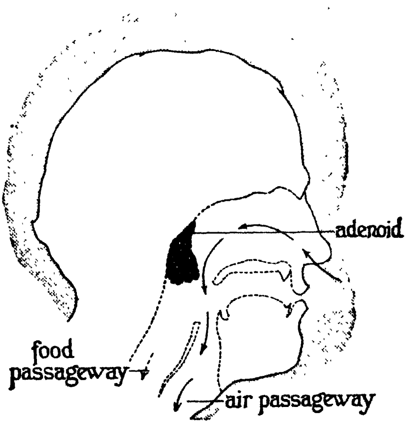
Keeping the Kidneys in Health

The kidneys also need care for the maintenance of good health. If too much protein is eaten, for example, excessive urea is formed and extra work is required of the kidneys to excrete the wastes. Then, too, the kidneys partly eliminate the toxic wastes of the body. Drinking plenty of water helps them to carry on this function more readily.

Keeping the Lungs in Health

It is important that the lungs be kept in good condition because they supply the body with oxygen and remove the poisonous carbon dioxide. Full, deep breathing helps to keep the lungs healthy by preventing the growth of disease germs, such as tubercle bacilli. Erect posture and physical exercise also help in keeping the lungs healthy. It is important, too, that the air passage to the lungs not be blocked by adenoids and enlarged tonsils. Moreover, the adenoids and tonsils often become infected and serve as a harbor for disease.

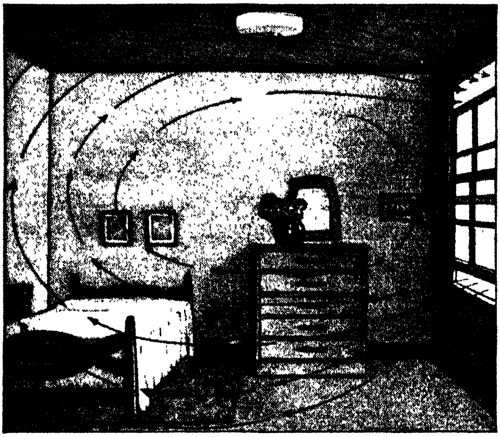
GROWTHS THAT INTERFERE WITH BREATHING



How do adenoids often block the passage of air to and from the lungs?

The importance of proper ventilation. The problem of ventilation is closely related to the efficiency with which the lungs do their work. This does not mean primarily that ventilation is necessary to

A WELL-VENTILATED ROOM



This illustration shows how air circulates in a room when a window is opened at the top and bottom.

keep the lungs supplied with plenty of fresh oxygen. Actually the content of air is only slightly changed by breathing, as shown by the table on page 270. Usually the slight loss in oxygen in an ordinary room, such as a bedroom, is fairly well replaced by the admission of air through the cracks and crevices around doors and windows. Additional ventilation, however, is needed for the following reasons:

1. To keep the temperature at approximately 68° Fahrenheit (66°–72°)
2. To keep the air moving. Since moisture evaporates from the skin, there is a blanket of highly humid air about the surface of the body. Air in motion scatters the blanket of moisture and reduces the humidity so that healthful evaporation can take place from the pores
3. To remove air laden with dust and impurities and to replace it with clean air

Restoring breathing by artificial respiration. Occasionally, because of electric shock, drowning, or asphyxiation, the lungs fail to work, and unless they can be rapidly forced into action, death will result. It is essential, therefore, that we should know what to do when such emergencies arise. The following directions will guide us.

In case of drowning, send for an inhalator and call a doctor as quickly as possible. Do not wait for them to arrive, but begin artificial respiration immediately by the *prone* pressure method. First loosen or remove the clothing, then turn the

PREPARING TO ADMINISTER ARTIFICIAL RESPIRATION

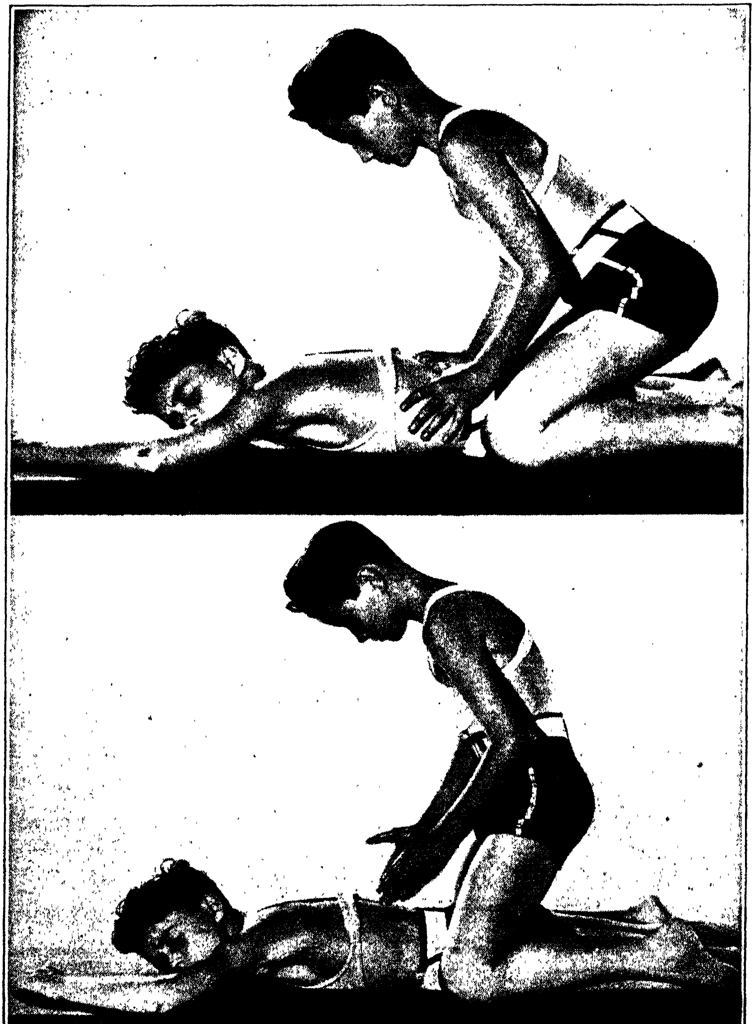
Ewing Galloway

The first step in giving artificial respiration is to place the victim on his stomach with his head turned to one side on his forearm.

victim on his stomach with his face resting on one arm. Next kneel across his body, placing your hands on his sides so that your little finger is on his lowest rib. Count "one," "two," and, as you do so, move forward and downward so that your full weight is slowly applied to his body. While counting "three," swing backward so as to remove your weight quickly. The sudden expansion of his chest permits air to pass into the lungs. Rest while counting "four" and "five," then repeat the performance. Do this twelve to fifteen times per minute. Perfect rhythm is highly essential. The method should be applied for at least four hours before hope is given up. Keep the victim warm, and as soon as he is conscious give him some strong, black coffee.

In case of gas poisoning and electric shock, artificial respirtion is one of the first methods to apply. Get the victim into the fresh air as soon as possible.

TWO IMPORTANT STEPS IN ARTIFICIAL RESPIRATION



Ewing Galloway

The first picture above shows the position a person should take as he presses slowly forward and downward on the back of a victim to bring about exhalation. The second picture shows how the person should remove his hands to allow inhalation.

Bathing and Its Relation to Health

Daily bathing is conducive to good health. If the two and one-half million sweat glands in the body were placed end to end, they would form a sewer ten miles long. Thus the problem of keeping the body clean and the pores open is exceedingly important.

Susceptibility to colds can frequently be avoided by a quick cold bath taken after morning exercise. Such a bath also seems to serve as an excellent tonic. Certain people, however, such as neurotic (nū-rŏt′ĭk) and anemic (ȧ-nē′mĭk) persons and those with circulatory disorders, should take cold baths very cautiously.

The Value of Exercise to Health

Exercise is a body builder. When the muscles are at work, the blood tubes expand and the cells receive greater quantities of food. As a result, the cells enlarge, multiply, and become more efficient in their operation. Without exercise they become small, flabby, and pale. Failure to take exercise may lead to indigestion, constipation, nervous prostration, sleeplessness, and anemia.

The need for exercise is universal. From the strongest athlete down to the bedridden invalid, there is the same general need. Not everyone, however, can take the same kind or amount of exercise. Some, for instance, should not play tennis. It would be foolish for a sedentary office worker to throw himself suddenly into such violent exercise. The muscles of his heart, in their frantic effort to pump sufficient blood, might be injured for life. For each individual, however, there are certain exercises that he can safely do. The inside worker usually should be contented with exercises that are of a moderate sort. Brisk walking in itself will probably provide sufficient exercise if enough of it is done. Athletic sports, such as baseball, swimming, rowing, ice skating, and tennis, are excellent when the individual can stand more strenuous activity. Setting-up exercises are valuable when a person has sufficient will-power to do them regularly every day.

The Effects of Alcohol and Narcotics on the Human Machine

It has been proved that the use of alcohol and such narcotics as morphine, cocaine, and nicotine seriously impair the efficiency of the human machine. Alcohol, for instance, stimulates the heart and relaxes the blood vessels. Its continued use may lead to heart disorders and inflammation of the liver and stomach. Its use may also result in the destruction of corpuscles, thereby rendering the body susceptible to the attacks of dangerous microbes.

The dangerous principle in tobacco is nicotine. It leads people into the tobacco habit, dulls the senses, stunts the growth, affects the heart, and irritates the mucous membranes of the throat and lungs.

Mental Health

When thinking about health, we frequently forget that there is such a thing as mental health. We know, of course, that fatigue and exhaustion poison the system, but so also do worry and violent emotions. If we become violently enraged during a meal, for example, we immediately impair the process of digestion. Such emotions as fear, panic, grief, hatred, and rage are unfavorable to health and consequently should be avoided. Also to be avoided are sorrow and worry. We should learn to cultivate a cheerful outlook if we are to maintain strong mental health.

Physical Examinations[1]

Finally, if we wish to conserve our health, we must be alert for signs of impairment or a breaking down of any of the organs of our body. Otherwise some organ may be damaged beyond repair before we can attempt remedial measures. We should, therefore, have a complete physical examination once a year by a reputable physician, and should have our teeth examined twice a year, so as to be sure that all parts of our body are functioning properly.

[1]See Unit Three, "Conquering Dangerous Microbes," and Unit Four, "Allies in Keeping Healthy," for more materials on the subject of health.

SUGGESTED ACTIVITIES

I. Self-Organization Summary

A. Cells, Tissues, and Organs
   1. What is meant by fundamental life processes?
   2. Name the important parts of a cell and state the use of each part.
   3. How can you distinguish between the tissues and organs of an organism?

B. Food Manufacturing
   1. Mention the important parts of leaves, roots, and stems.
   2. How do leaves, roots, and stems function as organs of nutrition?
   3. Explain the manufacturing of carbohydrates, proteins, and fats.

C. Foods as Fuels
   1. What facts should be considered in the planning of daily diets?
   2. How does each of the vitamins assist in carrying on life processes?

D. The Story of Digestion
   1. Give a detailed description of the digestive system of man.
   2. Trace food from the mouth to the blood, stating the mechanical and chemical processes that take place.

E. Circulation in Man
   1. Of what substances is the blood composed? What is the function of each?
   2. Trace a drop of blood through the circulatory system.
   3. How does the lymphatic circulation function?

F. Breathing
   1. Explain the breathing machinery of several different kinds of lower animals.
   2. How does the respiratory tract operate in the human body?
   3. What changes take place in the blood during inspiration and expiration?

G. Excretion of Waste Materials
1. Why is excretion a necessary process in the life of all plants and animals?
2. What waste materials are excreted from plants?
3. Describe a kidney and state the function of each part.
4. Explain how the skin serves as an organ of excretion.

H. The Skeletal and Muscular Systems
1. What three important functions are performed by the human skeleton?
2. Explain the purpose of each structural part of a bone, such as the femur.
3. Explain how the leading bones function in these parts of the body: (1) head, (2) trunk, and (3) appendages.
4. Name the two chief kinds of muscles and explain how each works.

I. Keeping the Human Machine in Health
1. Explain how autointoxication may be prevented or eliminated.
2. State the names and uses of the permanent teeth.
3. Explain how the kidneys and lungs may be kept in good condition.
4. Discuss the importance of proper ventilation.
5. State the effects of alcohol and narcotics on the human machine.
6. What is meant by mental health?

II. Laboratory Study

A. Microscopic Study of Plants
1. Prepare microscopic slides of fresh, living plant leaves, such as the Elodea. Watching the Elodea cells carry on their work will give you evidence that the leaf is really a busy place.
2. Sketch the cross sections of leaves, roots, and stems as they appear under the microscope, then label them in your drawing. State the function of each part. What relation do you see between such microscopic work and the subject of photosynthesis?
3. Place an aquatic plant under a glass funnel and submerge it in a jar of water. Now place the apparatus

in sunlight. Gas will be released which may be collected if a test tube filled with water is inverted over the stem of the funnel. The gas that accumulates in the test tube may be tested with a glowing splinter to prove that it is oxygen. This proves that oxygen is produced as a by-product of photosynthesis.

B. Microscopic Study of Animals

1. Dissect fish and frogs to show the parts of the digestive, circulatory, excretory, and respiratory systems. If it is preferred, a study of these animals may be made from charts and models. The anatomy of each specimen should not, however, be taken up in great detail. Comparisons should be made with the parts of the human skeleton. Examine such animal parts as hearts, kidneys, lungs, and livers, which may be secured from local meat markets.
2. Study prepared microscopic slides of the blood and its parts.

C. Study of Foods

1. By testing various fruits and vegetables, show that plants manufacture proteins, fats, and carbohydrates.
2. Outline balanced diets that contain the proper number of Calories for daily needs.

D. Demonstrations

1. Discuss and demonstrate various systems of setting-up exercises.
2. Demonstrate lifesaving by artificial respiration.

III. Display Posters

A. Colored pictures of fruits and vegetables mounted on cardboard charts. The vitamin content of each fruit and vegetable should be indicated.

B. Large drawings showing the anatomy of the human body. It may be interesting to picture the internal organs as mechanical structures, such as the cogs, wheels, and pistons of a typical machine.

C. Pictures of modern heating and ventilating systems mounted on stiff cardboard. An explanation should accompany each chart.

REFERENCES[1]

1. Barrows, William Morton. *Science of Animal Life.*
   a. Food getting and digestion in animals, pp. 27–44
   b. Respiration in animals, pp. 70–88
   c. The life processes of each of the animal groups, pp. 157–268
2. Hill, A. V. *Living Machinery.*
   a. The heart, pp. 79–119
   b. The lungs, pp. 119–163
   c. Physiology as a meeting ground of the sciences, pp. 233–275
3. Hough, Theodore; Sedgwick, William T.; and Waddell, J. A. *The Human Mechanism.*
   a. Foods and digestion, pp. 111–159
   b. Circulation of the blood, pp. 159–198
   c. Respiration, pp. 198–214
   d. Excretion, pp. 214–223
4. Shipley, Sir Arthur E. *Life.*
   a. Cells and their parts, pp. 7–21
   b. Feeding, pp. 21–28
   c. The nitrogen cycle, pp. 37–41
   d. Digestion, pp. 87–89
   e. Respiration, pp. 99–112
   f. Movement, pp. 115–160
   g. Reproduction, pp. 160–191
5. Transeau, Edgar Nelson. *Science of Plant Life.*
   a. Leaves and their structures, pp. 13–24
   b. Manufacture of food, pp. 25–35
   c. How plants use food, pp. 82–92
   d. Stems and their structures, pp. 102–136
   e. The structures and processes of roots, pp. 166–195
6. Williams, Jesse F. *Healthful Living.*
   a. The cells of the body, pp. 29–45
   b. Tissues as building materials, pp. 45–83
   c. Muscles, pp. 148–192
   d. Food and its uses, pp. 192–210
   e. The digestion of food, pp. 210–250
   f. The circulation of the blood, pp. 314–336
   g. The effect of alcohol and tobacco, pp. 507–525

[1]The pages listed here are those found in the editions indicated in the alphabetical list of references given at the end of this book.

7. *Book of Popular Science, The.*
   a. Glands and their known uses, Vol. 5, pp. 1711–1718
   b. A plant's life processes, Vol. 7, pp. 2207–2219
8. *Compton's Pictured Encyclopedia.*
   a. Human physiology and anatomy—outline, Vol. 11, pp. 208–209
   b. The operation of the human heart, Vol. 6, pp. 257–259
9. *New Wonder World, The.*
   a. Food and life, Vol. 10, pp. 369–384
   b. The machinery of our bodies, Vol. 10, pp. 324–349
10. *World Book Encyclopedia, The.*
   a. Life processes of living matter—outline, Reading and Study Guide, p. 8094
   b. Artificial respiration, pp. 2038–2040

VISUAL AIDS

Films (16 mm.)

A. Eastman Teaching Films, Inc., Rochester, New York.
   1. Green Plant. 1 reel, silent, $24.00.
      Pictures the life processes of a green plant
B. University of Kansas, Lawrence, Kansas.
   1. Circulation. 1 reel, silent, $2.00 per day.
      Traces the circulation and compares the human heart with that of the frog
C. Indiana University, Extension Division, Bloomington, Indiana.
   1. The Skin. 1 reel, silent, $1.00 per day.
   2. The Living Cell. 1 reel, silent, $1.00 per day.
   3. Body Framework. 1 reel, silent, $1.00 per day.
D. University of Chicago, Biological Science Service, Chicago, Illinois.
   1. Digestion. 1 reel, sound, rent—apply for rate.

Charts

Series	*Titles*
A. Schmeil Botany	Cell Structure; Leaf Structure; Stem Structure
B. Pfurtscheller Zoölogy	Paramecium; Starfish; Digestive System (Perch); Digestive System (Frog)
C. Frohse Anatomical	Digestive System (Man); Nervous System (Man); Eye and Ear

UNIT SEVEN

EXPLORING THE PLANT AND ANIMAL GROUPS

SUGGESTIONS TO THE TEACHER

The materials of the preceding units have for the most part been organized around human interests and daily needs. This unit, on the other hand, aims to present the materials of biology from the standpoint of scientific organization. It covers the classification of plants and animals, and provides an exploration of interesting details connected with various forms of life.

The classification of plants and animals should be carried far enough for the students to delve into the more important *classes*, *orders*, *families*, *genera*, and *species*. They should come to understand the meaning of all these terms and should realize that practically every form of life may be cataloged according to its characteristics. It is impossible, of course, to consider every form in a single book like this. Additional materials for use and study, however, may be found in the references at the end of the unit and in the Appendix.

OBJECTIVES

I. Facts and principles

A. To develop an understanding of the scheme for classifying plants and animals
B. To learn to identify some of the more important plants and animals
C. To arrange plant and animal life in a logical sequence
D. To explore some of the plant and animal groups by studying such details as peculiar habits, habitats, adaptations, enemies, modes of protection, food and food-getting methods, and economic importance
E. To study some of the structural changes that have taken place in living things over a long period of time

II. Attitudes

A. To develop an appreciation of biology as a science
B. To obtain a more complete picture of life in its varied forms
C. To stimulate an interest in the fascinating work of collecting, naming, and identifying specimens of living organisms

UNIT SEVEN

EXPLORING THE PLANT AND ANIMAL GROUPS

A FAVORABLE HABITAT

What different forms of life can you find in this picture?

A VISIT TO THE ZOO

PREVIEW

Have you ever visited a zoo? If so, you have noticed that a definite system is used for naming and grouping the various animals. Perhaps you have observed that certain sections of the zoo are given over to *birds*, other sections to *reptiles*, and still others to *mammals*. On the cages and pens of the mammals you may have noted such names as *Rodentia* (rodents), *Carnivora* (flesh-eating animals), and *Ungulata* (hoofed animals). Would you like to know why animals are given such names and how it is possible to classify so many different forms of living things? The animals at the zoo were not given these

ANIMALS OF THE WILDS

Courtesy Cleveland Museum of Natural History

This picture shows an African male lion at the left, a mother lion or lioness at the right, and two cubs. No animal is more ferocious than a lioness guarding her young.

names by guess or accident. The keeper knew exactly what name he should put on each cage or pen. In so doing, he merely followed a great scheme that has been developed for classifying plants and animals. In view of the fact that there are more than a million known species of living things, it became necessary to devise a way of sorting or grouping them according to their various characteristics. It was Carl Linnaeus (lĭn-nē′ŭs), a Swedish botanist, who originated a system for naming plants. This was in the year 1753, and since that time his system has been extended and revised so as to cover every kind of living thing.

Doubtless on various occasions as you have been tramping through fields or forests you have come across an odd bug, flower, or bird and have immediately asked, "What is this?" Perhaps you have taken your specimen to some botanist, zoölogist, or friend who has said, "Why this is a ——," or,

"This is a species of ——." Then you have longed for such a knowledge of living things yourself as would enable you to recognize plants and animals when you see them. That opportunity now comes to you. The following problems will direct your learning.

PROBLEMS

1. **Into what groups have plants and animals been sorted?**
2. **How have the plant and animal groups been organized and named?**
3. **What is there of interest in the plant groups?**
4. **What is there of interest in the animal groups?**

Problem 1. Into what groups have plants and animals been sorted?

Sorting the receipts of a football game. Let us imagine we are faced with the responsibility of counting the gate receipts from a football game. The money lies in scattered heaps on a large table in front of us. What plan can we devise to make the counting rapid and easy? Our first step is to separate the money into two stacks; namely, metal coins and paper bills. The next step is to sort the metal into stacks of copper, nickel, and silver coins; and the paper into piles of one-, five-, and ten-dollar bills. When we have completed the sorting, we can count the money very quickly. This part is easy because we have placed all the coins that are alike in the same stacks and all the bills that are alike in the same piles. How many stacks of coins and bills shall we have?

The classification of money may be represented roughly by the following table.

SORTED MONEY

Metal		*Paper*
Cents	Quarters	Ones
Nickels	Half dollars	Fives
Dimes	Dollars	Tens

IN QUEST OF SPECIMENS

Biology students like to observe plants and animals in their natural habitats.

PLANT AND ANIMAL PHYLA

Sorting Plants and Animals into Groups

Now, instead of money, suppose we have before us on the table miniature models of many of the large plants and animals and enlarged models of the tiny ones. How may we sort them? The answer is that we may proceed in very much the same manner as we did with the money. In the first place, we should make two divisions, one containing the plants and the other the animals. Taxonomists (tăk-sŏn′ō-mĭsts), that is, persons who classify plants and animals, have called these two divisions *kingdoms*. Each kingdom may next be sorted into groups, each of which will contain organisms that are similar in certain characters. The first subdivision of a kingdom is known as a *phylum* (fī′lŭm; plural, *phyla*, fī′lȧ).

How such groups are determined. Since the groups or phyla composing the plant and animal kingdoms must be very large to include the wide variations that exist in form and structure,

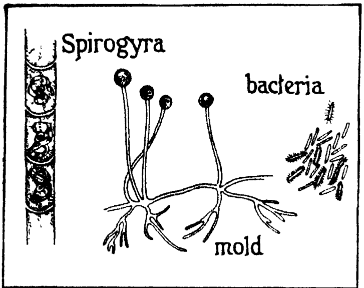
the members of a phylum have only certain general characters in common. Among the miniature plant models on our table are cone-bearing and flowering trees and shrubs; flowering herbs; bacteria and algae. The bacteria and algae are very simple microscopic plants that have no stems or leaves. We therefore place these simple plants in a phylum which the botanists call *thallophytes* (thăl′ō-fīts)[1], or seedless plants. The flowering plants and cone-bearing plants all have roots, stems, and leaves and are placed in a phylum called *spermatophytes* (spûr′mȧ-tō-fīts′), or seed plants.

Among the animal models on our table are such specimens as grasshoppers, crayfish, birds, and dogs. The grasshoppers and crayfish have external skeletons, jointed legs, and jointed or segmented bodies. The birds and dogs, however, have an internal skeleton, a part of which is a backbone that is made up of a number of small bones called *vertebrae* (vẽr′tē-brē). We group the grasshoppers and crayfish together in a phylum called the *arthropods* (är′thrō-pŏdz). The birds and dogs we place in a phylum called *chordates* (kôr′dāts). Thus, in a manner somewhat similar to the way in which money is sorted, plants and animals may be sorted into phyla on the basis of the characteristics which they have in common.

The English names of the plant and animal phyla, together with the characters and examples of each, are given in the tables on the following pages. These tables should be examined carefully, but need not be memorized at this time. A detailed study of the plant and animal phyla will be made later in the unit. When this study has been completed, the table as a whole should be memorized as a means of summarizing the phyla and their leading characters. It is to be noted that in this table *worms* are treated under one head, although they vary greatly in form and structure.[2]

[1]Some books give the scientific names of the phyla rather than the English names. For example, the Latin name *Thallophyta* may be used instead of the English name *thallophytes*.

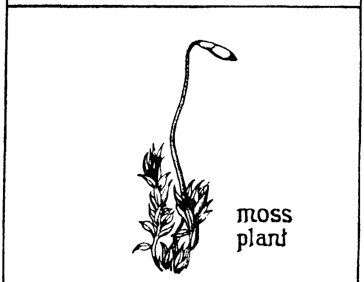
[2]There are really four distinct phyla of worms: Platyhelminthes (plăt′ĭ-hĕl-mĭn′thēz) (flatworms); Nemathelminthes (nĕm′ȧ-thĕl-mĭn′thēz) (roundworms); rotifers (rō′tĭ-fẽrz) (wheelworms); and annelids (ăn′ĕ-lĭdz) (segmented worms). To avoid the detailed discussion that otherwise would be necessary, they are all treated together.



Thallophytes (thăl'ō-fīts)

One- to many-celled bodies; no true stem or leaves; reproduction by cell division

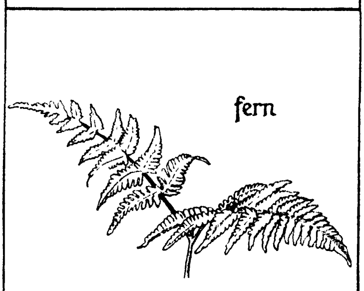
Examples: bacterium, fungus, alga



Bryophytes (brī'ō-fīts)

Stem and leaves, but no roots; alternation of generations

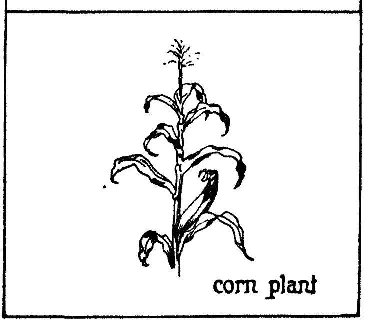
Examples: moss, liverwort



Pteridophytes (tĕr'ĭ-dō-fīts')

Vascular system; alternation of generations

Examples: fern, horsetail, club moss



Spermatophytes (spûr'mȧ-tō-fīts')

Reproduction by seeds

Examples: bean, grain, pine tree

Protozoans (prō′tō-zō′ănz)

One-celled bodies

Examples: amoeba, Paramecium

Porifera (pō-rĭf′ẽr-ȧ)

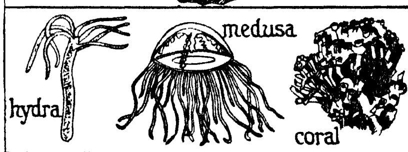
Porous bodies

Example: sponge

Coelenterates (sē-lĕn′tĕr-āts)

Bodies with cavity, the same opening usually serving for the admission of food and the excretion of wastes

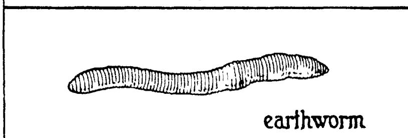
Examples: jellyfish, hydra



Worms

Slender, elongated bodies

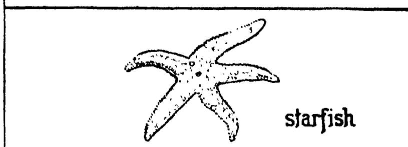
Examples: earthworm, hookworm



Echinoderms (ē-kī′nō-dûrmz)

Spiny-skinned bodies

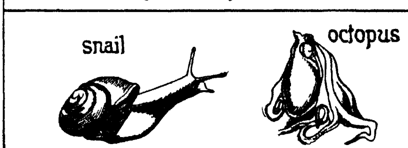
Examples: starfish, sea urchin



Mollusks (mŏl′ŭsks)

Soft bodies, usually within shells

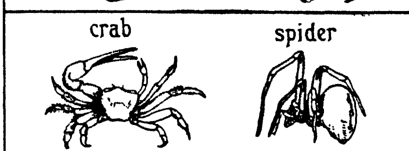
Examples: snail, octopus



Arthropods (är′thrō-pŏdz)

Segmented bodies with jointed appendages and chitinous exoskeletons

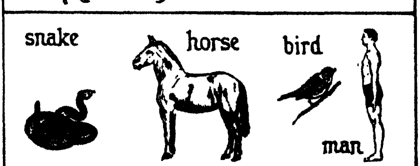
Examples: crab, grasshopper



Chordates (kôr′dāts)

Bodies with internal axial basis for skeletons

Examples: man, horse, bird



Problem 2. How have the plant and animal groups been organized and named?

THE SCHEME OF CLASSIFICATION

Under Problem 1 we learned that the members of the plant and animal kingdoms may be sorted into phyla. We shall now consider their subdivisions, the members of which have more characters in common than have the members of the phyla. The phylum arthropods, for example, includes such animals as grasshoppers, beetles, crayfish, and crabs. The grasshoppers and beetles are land animals that get oxygen through breathing tubes in their bodies. The crayfish and crabs, on the other hand, are water animals that secure oxygen through gills from the water. Since the grasshoppers and beetles differ widely from the crayfish and crabs in certain structures, they are placed in a different subdivision of the phylum known as a *class*. The grasshoppers and beetles belong to the class called *insects*, the crayfish and crabs to the class called *crustaceans* (krŭs-tā′shănz). Classes are then divided into *orders*, orders into *families*, families into *species*, and species into *varieties*.

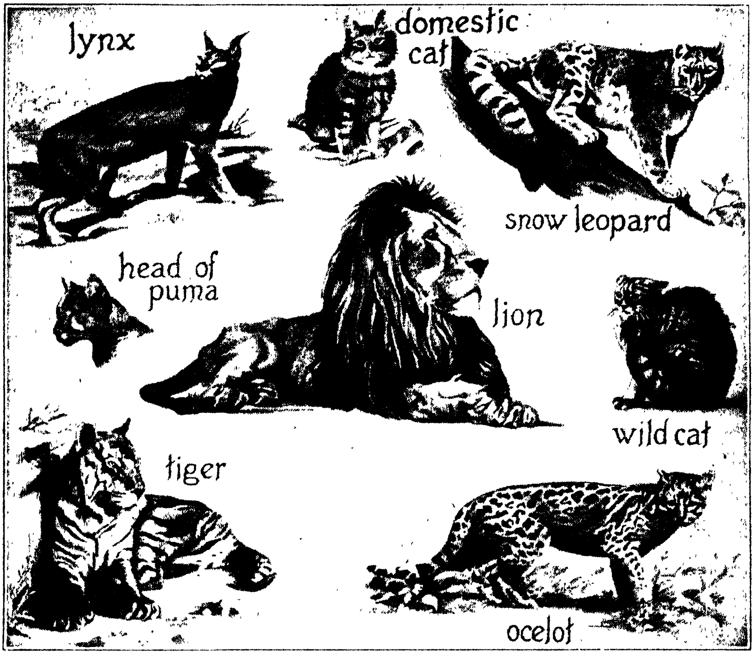
Likewise, zoölogists have divided the phylum chordates into four subphyla. The one that contains the largest number of animals, and consequently is of greatest interest to us, is the subphylum *vertebrates*. The character that separates the vertebrates from the other subphyla is the *spinal column*.[1] The tables on pages 304–305 show some of the classes and orders into which this subphylum is divided.

HOW "FELIX THE CAT" WAS NAMED

In the midst of all we have read and seen about Felix the cat, perhaps we have wondered many times why this famous animal was given such an odd name and just what the name means. As a matter of fact, the animal has two names, *Felix* and *cat*. Even the word *cat*, which seems so common to us,

[1] The three other subphyla of the chordates are simple forms that have an elastic rod of cellular tissue, called a *notochord* (nō′tō-kôrd), instead of a column of vertebrae extending down the dorsal side of their bodies.

MEMBERS OF THE CAT FAMILY



Courtesy *World Book Encyclopedia*

Some of the fiercest animals are close relatives of "Felix the cat."

must have had a beginning some way or other. Let us see whether we can discover just how the cat was named.

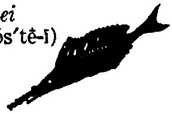
A review of the classification of animals shows that the cat belongs to the phylum chordates, the subphylum vertebrates, the class mammals, and the order Carnivora. The order Carnivora in turn is broken up into subdivisions, each of which is known as a *family*. Thus when we think of animals somewhat like the cat, such as lions and tigers, we think of the *feline family*, the Latin name of which is *Felidae* (fē′lĭ-dē). Cats, lions, and tigers are so different from one another, however, that each of them belongs to a separate division called a *genus* (jē′nŭs; plural, *genera*, jĕn′ẽr-ȧ). The name of a genus is called the *generic name*. The generic name of a cat is *Felis* from which, of course, we derive the name Felix.

CLASSES

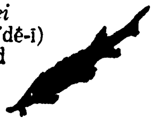
Fishes

Orders

Teleostei
(tĕl′ē-ŏs′tē-ī)
bony fishes



Ganoidei
(gȧ-noi′dē-ī)
armored fishes



Elasmobranchii
(ē-lăs′mō-brăŋ′kĭ-ī)
cartilaginous fishes

Dipnoi
(dĭp′nō-ī)
lungfishes

According to the geologic time scale illustrated on pages 670–671, fishes were one of the earliest forms of animals that may be traced through fossils. Before their time animal life seems to have been limited to invertebrates and unicellular organisms, all of which lived in the water.

Amphibians

Orders

Urodela
(ū′rō-dē′lȧ)
tailed amphibians

Anura
(ȧ-nū′rȧ)
tailless amphibians

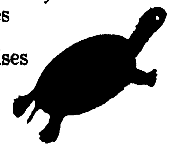
According to fossil evidence the amphibians are somewhat younger than the fishes. Originally water animals, they gradually changed in form and structure so they could live on land as well. Today they are admirably adapted to a joint land and water existence.

Only two groups of amphibians are listed here. There is a third unimportant group that lives only in tropical regions. The individuals of this group have neither feet nor limbs and are wormlike in shape. Their eyes are buried under their skin, an adaptation to their burrowing habits.

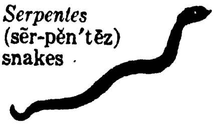
Reptiles

Orders

Chelonia
(kē-lō′nĭ-ȧ)
turtles and tortoises

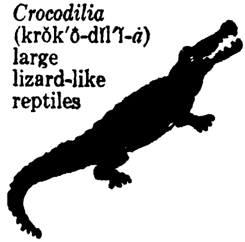


Serpentes
(sẽr-pĕn′tēz)
snakes



Lacertilia
(lăs′ẽr-tĭl′ĭ-ȧ)
lizards

Crocodilia
(krŏk′ō-dĭl′ĭ-ȧ)
large lizard-like reptiles



The reptiles are still younger than the amphibians, being the first important animals that adjusted themselves to a complete existence on the land.

A more detailed classification will be found in the Appendix.

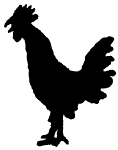
CLASSES

BIRDS

ORDERS

Anseriformes
(ăn′sēr-ĭ-fôr′mēz)
goose-like birds

Galliformes
(găl′ĭ-fôr′mēz)
fowl-like birds



Charadriiformes
(kȧ-răd′rĭ-ĭ-fôr′mēz)
shore birds

Passeriformes
(păs′ẽr-ĭ-fôr′mēz)
perching birds

Coraciiformes
(kôr′ȧ-sī′ĭ-fôr′mēz)
roller-like birds

Falconiformes
(făl′kō-nĭ-fôr′mēz)
birds of prey

MAMMALS

ORDERS

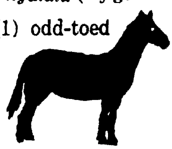
Monotremata
(mŏn′ō-trē′mȧ-tȧ)
egg-laying mammals

Chiroptera
(kī-rŏp′tẽr-ȧ)
winged mammals

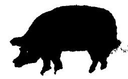
Insectivora
(ĭn′sĕk-tĭv′ō-rȧ)
insect-eating mammals

Ungulata (ŭŋ′gū-lā′tȧ) hoofed mammals

(1) odd-toed

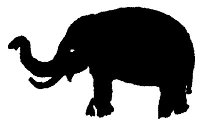


(2) even-toed



Rodentia (rō-dĕn′shĭ-ȧ)
gnawing mammals

Proboscidea
(prō′bŏ-sĭd′ē-ȧ)
mammals with a trunk



Cetacea (sē-tā′shē-ȧ)
fishlike mammals

Edentata (ē′dĕn-tā′tȧ)
toothless mammals

Marsupialia
(mär-sū′pĭ-ā′lĭ-ȧ)
pouched mammals

Carnivora (kär-nĭv′ō-rȧ)
flesh-eating mammals

Primates (prī-mā′tēz)
erect mammals

HOUSEHOLD PETS

Felis domestica angora. What a name for such innocent little creatures!

We know from observation that even cats are of different kinds; hence their genus is broken up into *species*. In biology the name of a species is always called the *specific name*. Strange as it may seem, the name of a species includes the name of the genus to which it belongs. Thus the specific name of a domesticated cat is *Felis domestica*. Whenever certain variations occur in a species, such as length of hair, color, and size of claw, the species is broken up into *varieties*. For instance, there are several varieties of cats, such as Angora, Persian, and Maltese. In order to show completely how an animal is classified, scientists often add the name of the variety to the generic name and the specific name. Thus an Angora cat completely tagged with all its names bears the label *Felis domestica angora*.

The complete classification of an Angora cat then may be expressed as follows:

Kingdom: Animal
 Phylum: Chordates
  Subphylum: Vertebrates
   Class: Mammals
    Order: Carnivora
     Family: Felidae
      Genus: Felis
       Species: *Felis domestica*
        Variety: *Felis domestica angora*

It may be helpful at this time to review Problems 1 and 2 and the tables on pages 301 and 305. Such a review will help us to understand more clearly how classification is derived. It may also be helpful to examine the more extensive classification of plants and animals given in the Appendix. Many of the terms in this classification will be unfamiliar. However, we can readily follow through the various steps in the sorting process to see how a common corn plant, *Zea mays*, and man, *Homo sapiens*, have acquired the names by which they are known scientifically.

Problem 3. What is there of interest in the plant groups?

In order to present a systematic organization of this problem, these groups of plants will be discussed on the following pages:

The Simplest Forms of Plant Life—the Thallophytes
A Peep into the Land of Mosses—the Bryophytes
Ferns from the Shady Woods—the Pteridophytes
The Nobility and Royalty of the Plant Kingdom—the Spermatophytes

INTRODUCTION TO THE PLANT KINGDOM

Where plants are found. In Unit One it is shown that plants are capable of adapting themselves to a great variety of climatic conditions. In fact, they are so generally distributed over the land that we can scarcely think of a region without them. Nor are their habitats limited entirely to the land, for many flourish in water, both fresh and salt. When we think of the different types of vegetation, those found in forests, swamps, meadows, and the like, we can see that nature has provided a beautiful design for covering the earth.

Plants as living things. For those who have not studied plants closely, it is hard to realize that such stationary organisms as plants are really alive, and that much activity goes on within their bodies. The difficulty is probably due to the

PLANTS THAT BRING LIFE AND BEAUTY TO THE PLACES THEY INHABIT

Courtesy William Tricker, Inc.

What an unsightly mudhole this plot of ground would have been without the presence of such plants as lotus, lilies, water hyacinths, and various ornamental grasses.

fact that there is a common tendency to associate life with the ability to move about. We can readily see the error in such an impression, however, when we remember that certain species of bacteria and algae, which of course are plants, have the power of locomotion. On the other hand, some animals, such as the sponge, do not move. The general principles of living, then, are similar in both plants and animals, except that plants do not have a system of nervous control. The functions of all living organisms may be summarized as follows:

1. Food getting
2. Digestion
3. Circulation
4. Assimilation
5. Respiration
6. Excretion
7. Reproduction
8. Nervous control (animals only)

THE SIMPLEST FORMS OF PLANT LIFE
THE THALLOPHYTES

General characteristics. The *thallophytes,* which compose the simplest phylum of the plant group, are unlike the forms of plants most familiar to us. These tiny organisms have a body, known as a *thallus,* but do not have stems or leaves. The form of the thallus varies widely and consists of one or several cells, depending upon the species.

Thallophytes are divided into the subphyla[1] *algae* (al′jē) and *fungi* (fŭn′jī). Most algae are water-loving plants that contain chlorophyll and are able to make their own food. Fungi do not have chlorophyll and are of two types: the *parasites,* which obtain their food from a living host, and the *saprophytes* (săp′rō-fīts), which live upon dead or decaying organic matter.

WATER-LOVING PLANTS—ALGAE

Economic importance of algae. The *algae* are of great value as food for fish and other water animals. They serve these animals in about the same way as grasses and other *herbaceous* (hẽr-bā′shŭs) plants (plants that do not have woody stems) serve land animals. The people of certain countries also consume them as food. Agar, used in the preparation of culture media for growing bacteria, is obtained from red algae. The fossil shells of a one-celled form of alga, the diatom, are used in certain types of cleansing preparations.

Classes of algae. For purposes of discussion the algae may be divided into four classes on the basis of color: the *blue-green,* the *green,* the *brown,* and the *red algae.* It happens, however, that not all algae are of the color indicated by the name of their class. For example, the Red Sea owes its name and color to a red species of blue-green algae.

The Blue-green Algae

Fresh water is usually the home of the blue-green algae, but they also live in the sea and in brackish water along the coasts. In moist climates they may also be found growing as gelatinous

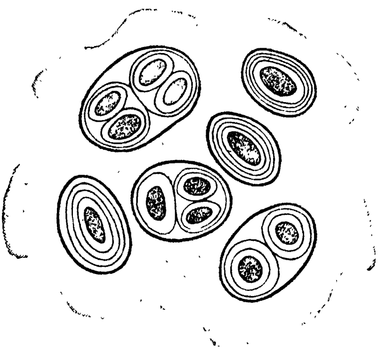
[1]Some authorities consider *lichens* a third subphylum of thallophytes.

masses on rocks, trunks of trees, and similar places. Some of the blue-green algae have become adapted to various types of moist soils and occasionally become pests in the greenhouse.

In their ability to adapt themselves to unfavorable conditions these algae are second to none. They have been known to remain alive in dried soil for a period of over fifty years. Their hardiness is also demonstrated by the fact that they can live in a frozen condition for several months, or can endure the heat of hot springs at a temperature so high that no other plant could possibly survive in it.

The following forms of blue-green algae will serve to illustrate the general characteristics and habits of the whole group.

TINY PLANTS INCLOSED IN JELLY-LIKE SHEATHS GLOEOCAPSA

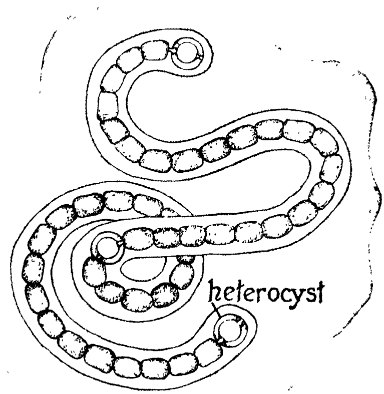


The drawing shows single cells and small groups formed by the process of cell division. These cells are held together by a mucilage-like substance. (Diagrammatic)

A microscopic "huddle"—Gloeocapsa. The Gloeocapsa (glē-ō-kăp′să) appear as patches on damp tree trunks, rocks, walls, and the like. Each patch is a colony of one-celled plants held together by means of a gelatinous substance which they secrete. When examined under the microscope, some of the cells may be seen dividing into two parts. Each part becomes a new plant that grows as large as the original parent cell, and then it too divides. This process illustrates the simplest of all the forms of reproduction; namely, *direct cell division.*

Microscopic "necklace"—Nostoc. Nostoc (nŏs′tŏk) is an alga that is somewhat similar to the Gloeocapsa in habit, size, and structure. It appears as jelly-like masses in damp places, but microscopic examination reveals that the cells are strung along in a single row, forming a necklace-like chain or filament. The cells in the chain are not all alike. At regular intervals larger colorless cells called *heterocysts* (hĕt′ẽr-ō-sĭsts) occur.

CELLS THAT FORM CHAINS
NOSTOC

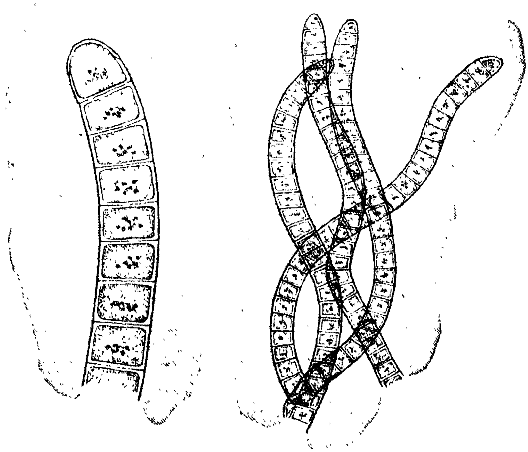


The chainlike filament represents a colony of individuals. The smooth curve setting off the drawing from the gray background is not a part of the plant structure. (Greatly enlarged)

Nostoc has a peculiar form of reproduction. The necklace-like chain breaks apart between two heterocysts. The newly formed smaller chains start new colonies that increase in length by cell division. Finally, after growing, these chains break into segments, and reproduction continues.

Tiny plants that quiver — Oscillatoria. The Oscillatoria (ŏs′sĭl-ȧ-tō′rĭ-ȧ) are found in great abundance in all kinds of wet places. They may be seen on the surface of lakes and ponds, or in the form of filmy growths on wet soil and rocks. As shown in the illustration herewith, these algae consist of short flattened cells fastened together to form filaments. They are called Oscillatoria because their filaments exhibit remarkable oscillations, swaying forward and backward as well as from side to side.

BLUE-GREEN ALGAE THAT OSCILLATE



These plants, Oscillatoria, get their names from the peculiar waving, gliding movements of their filaments. (Greatly enlarged)

The Green Algae

It is doubtful that any other group of plants presents such a wide range of forms, structures, and life histories as the green algae. Because of this fact the plants are difficult to describe as a whole. They are called green algae because of their characteristic grass-green color. In early spring there is scarcely a pool or runlet that is not made brighter by some of these plants. A few interesting forms that may easily be procured for study are: Protococcus (prō′tȯ-kŏk′ŭs) and Spirogyra (spī-rȯ-jī′rȧ), described on the following pages, Cladophora (klȧ-dŏf′ȯ-rȧ), a green alga having branched filaments, and Oedogonium (ē-dȯ-gō′nĭ-ŭm), a filamentous green alga.

Little spheres of green — Protococcus. Doubtless we have seen Protococcus appearing as a green coat on the north sides of tree trunks and old fences. Before we knew what it was, we may have thought that the objects were really painted with a brush. Had we scraped off some of the Protococcus, however, and examined it under a microscope, we should have found it composed of many colonies of living spherical cells. In fact, each Protococcus is a single cell. (See Unit Two, page 83, for an illustration of Protococcus.)

Protococcus is available any month of the year, and is admirably suited for study of the conspicuous features of a living cell. By examining it under the microscope, we can see how a cell divides and how, before the halves are entirely separated, they may divide again so as to form a group or colony of cells. Although Protococcus consists of only a single cell, yet it carries on all the life functions of the higher groups of plants that have roots, stems, and leaves.

The green scum of ponds — Spirogyra. No doubt when we have seen Spirogyra appearing as scum on the shallow water of a pond, we have considered it very unattractive. When viewed under the microscope, however, Spirogyra is an object of beauty. Its cylindrical cells are arranged end to end to form slender threadlike filaments. The cells are all alike in form and structure, and each one performs every function of a plant, such as making food, growing, and reproducing.

Chloroplasts (klō′rŏ-plăsts), or bodies containing green coloring matter, appear as bands arranged spirally within the cell walls. (See Unit Two, page 82, and Unit Eleven, page 582, for illustrations of Spirogyra.)

The Brown Algae

The two groups of algae we have just considered are the most common fresh-water forms. Brown algae, with few exceptions, are marine (salt-water) plants. They include the largest and most conspicuous seaweeds, some of which grow to be more than a hundred feet long. These plants grow best in cold waters, being found along the shores of the North Atlantic and North Pacific oceans and reaching their greatest development in the Arctic regions and the Antarctic realm. Most of them are anchored by *holdfasts* and have strong bodies that enable them to withstand the whipping of waves and currents.

This group of algae is composed of three distinct forms: the *filamentous forms*, the *rockweeds*, and the *kelps*. The largest forms are the kelps. They grow in great abundance and are profitably used as sources of fertilizer and iodine. Those found along the Pacific Coast often attain a length of 150 feet.

A large area in the Atlantic Ocean is known as the Sargasso Sea because so much sargassum (sär-găs′*ŭ*m), or gulfweed, floats upon the water. This sargassum is torn loose from its anchorage along the coasts and is carried by the Gulf Stream to mid-ocean, where, because of eddies and calms, it collects in great masses. This brown alga has slender branching stems with leaflike structures and air bladders that resemble berries.

The Red Algae

Like the brown algae, the red algae are mostly marine plants. They are noted for their graceful forms and beautiful colors. This is especially true of the feathery Ptilota (tĭ-lō′tȧ). Red algae reach their greatest development in the warmer waters of the temperate or the tropical seas. Although many of them grow in shallow water, a few grow at great depths. Some of them, the *corallines*, contain lime deposits in their cell walls and have branching forms that resemble corals.

FLESHY FUNGI

General Biological Supply House

These fungi, commonly called mushrooms, are the puffball, the morel, the deadly amanita, and the Psalliota arvensis. All but the amanita are edible.

"Poor Relations" of the Plant Kingdom — The Fungi

General characteristics. The *fungi* form a very large and varied group, ranging in size from the microscopic one-celled forms up to the enormous bracket fungi, which may weigh as much as thirty pounds. Since these plants are either parasites or saprophytes, they may be considered "poor relations" of the plant kingdom. They thrive best in shady moist places and destroy such materials as pillars in mines, railroad ties, beams under porches, and fruits stored in cellars. Structures of wood stand for centuries in dry regions because the fungi do not thrive there.

The fungi are related to the algae, but they are different in that they do not possess chlorophyll (green coloring matter).

The body of a fungus plant is composed of threadlike filaments called *hyphae* (hī′fē). A mass of hyphae is called a *mycelium* (mī-sē′lĭ-ŭm). The nature of the mycelium depends upon the form of the filaments of which it is composed. In molds the mycelium may be loose in structure; in mushrooms it is rather firm and compact; and on trees and

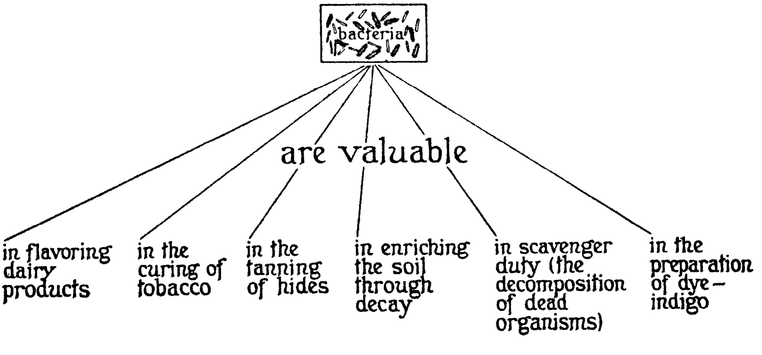
timber it forms a woody shelf. Tissues as we find them in higher forms of plants never occur in the fungi.

Details concerning the reproduction of black mold, a fungus, are given in Unit Eleven, pages 576 and 583.

Bacteria—the Smallest but Mightiest Plants

Although *bacteria* are the smallest of known living forms in all the plant kingdom, they are among the most important. This is apparent from a study of some of their effects, discussed in Unit Three. In that unit, however, most of the bacteria are charged with all sorts of crime. Hence it is proper now to come to their defense and tell some of the ways in which they render service.

Nonpathogenic bacteria. It is through the work of bacteria that dead plants and animals are returned to the soil so that their raw materials may again be taken up by growing plants. Certain nitrogen-fixing bacteria, which grow in the roots of such plants as clover, alfalfa, and cowpeas, aid the farmer by taking free nitrogen from the air and making it over into a compound that can be absorbed by the roots of such important plants as corn, wheat, potatoes, and cotton. Certain bacteria give flavor to cheese and butter and help make sauerkraut a tasty and valuable food. Other bacteria, commonly called "mother of vinegar," help to convert cider into vinegar. Still other bacteria assist in the curing of tobacco, in the tanning of hides, and in the production of many other important commodities.



Other "Poor Relations" That We Should Know

Molds as pests. Molds grow in many places and under varying conditions, but they thrive best in warm, damp places and in the absence of light. They always bear spores. The spores of *bread mold* exist everywhere in the air. We can easily verify this statement by placing a piece of damp bread under a glass jar and watching results. When the spores germinate, they develop into tubelike hyphae that form a mycelium. The hyphae soon send out many branches, some of which penetrate the bread and absorb food. Other branches spread over the surface. At the end of some of the upright branches little black dots appear. These are spore cases called *sporangia* (spô-răn'jĭ-ȧ), within which countless numbers of spores develop. When the spore cases have ripened, they burst open and the spores are blown about in the air. Here they remain until they find another substance on which they may alight and grow. (See Unit Eleven, page 576, for illustration of mold.)

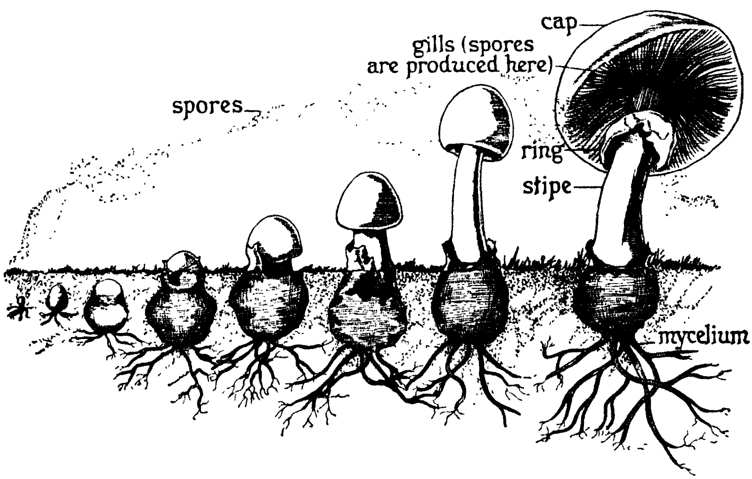
Bread mold, of course, renders bread unfit for use as food. It also attacks other kinds of food, such as pies, cakes, cookies, and flour. Other molds grow on canned foods unless they are securely sealed or covered with paraffin. These molds give the foods a disagreeable flavor and in time will bring about their complete destruction. Some molds even attack fresh fruit. Consequently the fruit is often wrapped carefully in paper to prevent contamination.

How molds are helpful. Since molds injure many useful things, such as foods, leather goods, paper, and clothing, we may conclude that all molds are harmful. Such an impression, however, is erroneous, for some molds are helpful. They secrete more different kinds of enzymes than any other fungi. They liquefy fats, digest certain proteins, and help to liberate oxygen. Certain molds are important in the making of cheese. This is especially true of molds which form on Camembert and Roquefort cheeses, noted for their peculiar flavor. Other molds, associated with other fungi, aid in the general processes of decay. They help to convert the leaves of trees, which fall

to the ground in autumn, into the rich soil of the woodlands. They also aid in the decay of wood and other organic matter.

Mushrooms and toadstools. *Mushrooms* usually grow in the rich damp soil of fields and woods and on decayed logs or trunks of trees. Great care should be exercised in gathering them for food, since it is extremely difficult to distinguish the poisonous from the nonpoisonous forms. One of the greatest differences is that the poisonous forms have a bulblike growth beneath the ground. Edible forms are cultivated in caves, cellars, and specially constructed houses, where they receive the proper moisture and warmth and very little light.

THE LIFE STORY OF THE MUSHROOM



Reproduction begins with formation of spores in the gills or rib-like bottom of the cap. These spores then fall to the ground and give rise to a mass of rootlike threads called the mycelium. The mushrooms are produced upon the mycelium.

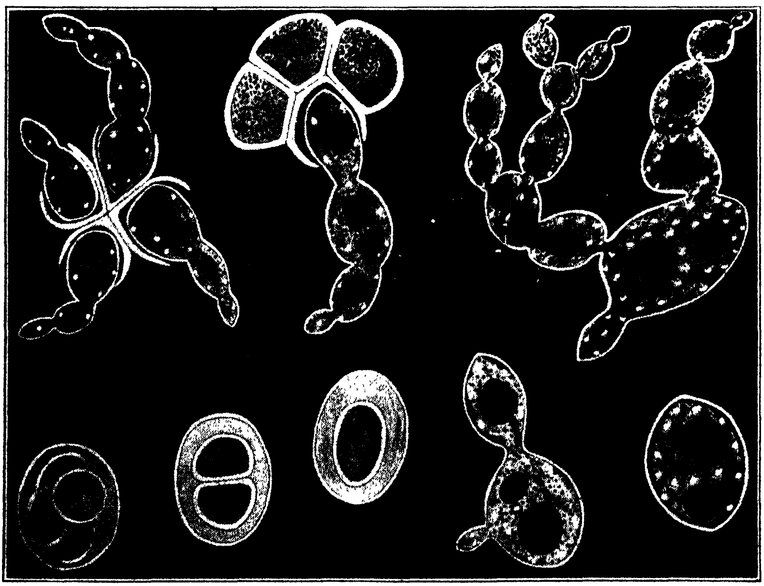
The foregoing illustration presents the life history of the extremely poisonous mushroom *Amanita muscaria* (ăm′ȧ-nī′tȧ mŭs-kā′rĭ-ȧ). The real vegetative body of this mushroom is the mycelium, which spreads in the soil or the decayed materials upon which it lives. The mycelium may grow for a long time before the fruiting bodies which we call mushrooms appear above the surface. These fruiting bodies grow very rapidly,

first appearing as "buttons," then as large umbrella-shaped structures. Uninformed persons think mushrooms develop over night because they consider only the fruiting bodies above the surface.

Plants that produce fermentation — yeast plants. The tiny one-celled *yeast plants* are for the most part useful allies of man. Occasionally, however, they annoy us, as when they cause canned goods to spoil or to take on a peculiar flavor. Their effects, good or bad, come from the fact that they are the cause of fermentation. Substances known as *enzymes* or *ferments* form in the yeast cells. These enzymes then escape and attack sugar in solution, breaking it up into alcohol and carbon dioxide. Chemically the action may be expressed as follows:

$$\underset{\text{sugar}}{C_6H_{12}O_6} \rightarrow \underset{\text{alcohol}}{2C_2H_5OH} + \underset{\text{carbon dioxide}}{2CO_2}$$

PLANTS THAT PRODUCE FERMENTATION
YEAST PLANTS



Jung, Koch & Quentell Botany Chart—Courtesy A. J. Nystrom & Company

Under favorable conditions, such as warmth, moisture, and the presence of sugar, yeast plants reproduce rapidly by budding. The illustration shows buds forming in chains.

That yeasts are about in the air may be shown if fruit juice is allowed to stand in an open container. Within a few hours the process of fermentation will begin. Cultivated yeasts are supplied to the market in the form of compressed or dried yeast cakes. These are used in the making of bread and are eaten to aid the process of digestion. Yeast is also used in the production of commercial alcohol.

Some bacteria also cause fermentation. The souring of milk, for example, is due to bacteria.

Plants that are parasites. There are about sixty-five thousand forms of fungi which get food from other plants, but of course it is possible to consider only a few at this point. Among these are the smuts and rusts, which are parasitic on corn, wheat, oats, and other grasses. Smut on corn may be readily recognized by its black spongy appearance. The matured spores form large masses on the young ears and tassels. Smut also attacks wheat, bringing about great destruction to the heads as they ripen on the stalks. In addition, wheat suffers greatly from rusts, which attack both stems and leaves. In fact, wheat rusts probably cause a greater annual loss than any other parasitic fungi. Oats, too, are attacked by smut, which damages the heads, and by rusts, which damage stems and leaves. Another fungus, known as *mildew*, brings grief to fruit and vegetable growers by causing the destruction of fruits and the rotting of potatoes. Still other fungi cause wilted and yellow leaves, peculiar growths, or sunken spots on trees. A further discussion of fungi may be found in Unit Nine.

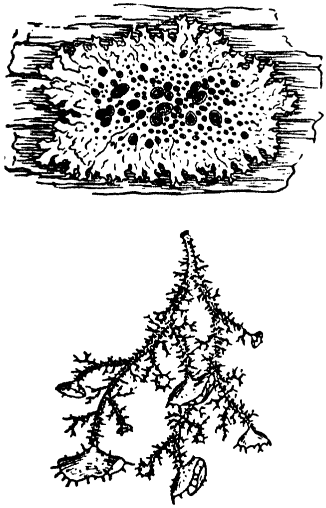
AN OATS THIEF

Illinois Agricultural Experiment Station

Smut often attacks as many as 35 per cent of the heads of oats.

Fungi and algae in partnership — lichens. Most people are familiar with *lichens* (lī′kĕnz) because they are so common. One form has a body like a crust and grows on the bark of trees, on rocks, and sometimes on the ground. Another form, consisting of a body with slender branches, grows in abundance in the Arctic region, where it serves as food for the reindeer and is known as reindeer moss. Still another form is the famous staghorn lichen of the north woods.

PARTNER PLANTS



General Biological Supply House

Above, Physcia, a crustlike lichen; below, Usnea, a branching lichen.

Strange to say, lichens are not single plants, but consist of algae and fungi together. The fungi live upon food made by the algae and in return furnish water for the algae. The tiny threadlike hyphae of the fungi completely surround the cells of the algae and keep them from drying out. Thus the close relationship between the two plants permits lichens to live in places where neither the fungi nor the algae could live alone. Such a condition of partnership in which both partners profit by the relationship is known as *mutualism* (mū′tū-ăl-ĭz′m). Other interesting examples of mutualism, such as those of the sea anemone and the hermit crab, the ants and aphids, are described in Unit Nine.

A PEEP INTO THE LAND OF MOSSES THE BRYOPHYTES

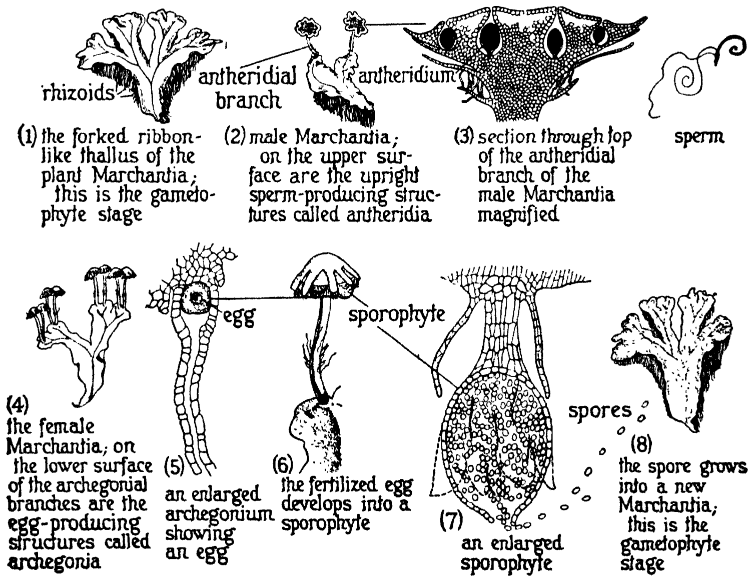
General characters. The *bryophytes* are somewhat more complicated in structure and life history than the thallophytes we have just been studying. They include the *liverworts* and *mosses* and rarely attain a height or length of more than a few inches. Most species live upon the land, usually in moist

places, although some live in dry habitats. An interesting fact about these plants is that they resume growth even though they have been subjected to long periods of drouth. As contrasted with the thallophytes, the bryophytes have very little economic importance.

The Liverworts

Plants that look like livers. The *liverworts* are peculiar little flat green plants that may be found growing on the surface of water, on the bark of trees, and in moist places. One of the most common genera is the Marchantia (mär-kăn′shĭ-ȧ). This interesting plant has a forked, ribbon-like thallus that creeps

THE LIFE STORY OF THE FORKED, RIBBON-LIKE PLANT—MARCHANTIA



After reading the related text, use the above drawings to explain how the Marchantia interestingly alternates between the sexual and asexual methods of reproduction.

along the ground. Like all bryophytes, the Marchantia has no roots, but is anchored to the substratum[1] by hairlike

[1]Substratum — the substance on which a plant grows, such as rocks, soil, water, and the tissues of other organisms.

structures called *rhizoids* (rī'zoidz), which absorb water and other materials for nourishment.

Instead of producing spores directly from its body as do certain thallophytes, the Marchantia has male and female sex organs. These organs are borne on special upright, umbrella-like branches that grow from the upper side of the thallus. The branch that bears the male sex organ is called the *antheridial branch,* and the organs themselves are called the *antheridia* (ăn-thẽr-ĭd'ĭ-ȧ). Many *sperm cells*[1] or male *gametes*[2] develop in each antheridium. The branch that bears the female sex organs is called the *archegonial branch,* and the organs are called the *archegonia* (är-kė-gō'nĭ-ȧ). Only one *egg cell*[3] or female gamete develops in each archegonium. The sperms swim about in water provided by the dew or rain. Finally one of them swims down the neck of an archegonium and unites with the egg. This union of an egg and a sperm is called *fertilization.* The product of the union is called a *zygote* (zī'gōt).

A fertilized egg, or zygote, grows by dividing, and forms a spore-bearing structure called a *sporophyte* (spō'rȯ-fīt). When the spores that grow within the sporophyte are ripe, the case opens and the spores are scattered. Each spore, if it germinates, then develops into a thallus body called a *gametophyte* (gȧ-mē'tȯ-fīt). Half of the gametophytes give rise to male sex organs, and the other half to female sex organs. Such a life history, in which one type of generation alternates with another type, is referred to as *alternation of generations.* This topic will be treated again in Unit Eleven.

The Mosses

Nature's green carpets. More familiar to most people than the liverworts are the *mosses.* These interesting plants may be found on trees, stones, or soil, and in either wet or dry regions. They consist of many little leafy branches held in place by tiny rootlike rhizoids. Since they grow very close together, an

[1] A sperm cell is also called a *sperm.*
[2] A gamete is a uniting cell.
[3] An egg cell is also called an *egg.*

abundant growth often has the appearance of soft, velvety carpet. The reproductive process in mosses is similar to that of the liverworts.

Mosses that become coal-like — peat. Certain species of aquatic mosses called Sphagnum (sfăg'nŭm) often fill up small ponds with a dense growth that dies in its lower parts but continues to grow in its upper parts. The dead mass of lower parts does not decay, but forms a compact substance called *peat*. In certain regions of Eurasia and North America great quantities of peat occur. In some of these regions it is cut into blocks and after being allowed to dry is used as fuel.

FERNS FROM THE SHADY WOODS
THE PTERIDOPHYTES

General characters. Ferns and fernlike plants, such as horsetails and club mosses, belong to the phylum called *pteridophytes*. This phylum is midway between the bryophytes and the spermatophytes, or seed-bearing plants. The pteridophytes differ from the thallophytes and bryophytes in that they have a large sporophyte consisting of a stem, leaves, and true roots. In other words, they may be considered the most highly organized plants that do not have seeds.

Some of the pteridophytes grow to enormous sizes, the stems often reaching a height of from ten to fifty feet, and the leaves attaining a length of ten to thirty feet. Their great growth may be attributed to the presence of a *vascular system* composed of conductive tissues through which water and raw food materials move readily from the roots to the leaves. It would be impossible for such large land plants to grow high above the soil without an efficient system of transportation.

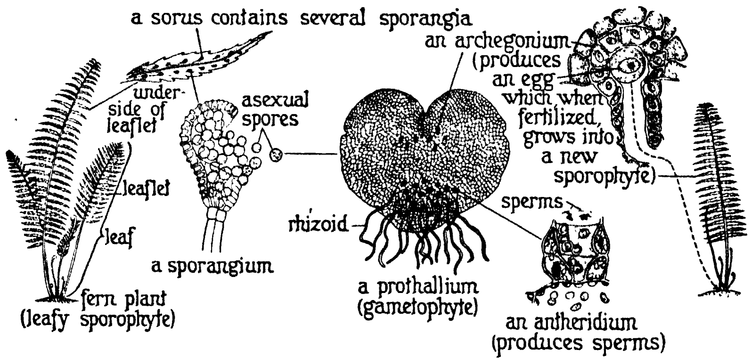
The pteridophytes include three groups: the *true ferns*, the *horsetails*, and the *club mosses*. We shall consider each of them separately.

THE TRUE FERNS

Plants with feather-like leaves. In the tropics some of the *ferns* grow as large as trees, but in the United States and other temperate regions they consist only of beautiful leaves reaching

out of the ground. Nearly everybody recognizes ferns by these finely divided leaves. They cannot be properly studied, however, unless we go to the shady woodlands, swampy lands, and other places where they grow in their natural habitat.

THE LIFE STORY OF A FERN



The leafy sporophyte (asexual generation) of this plant is the common fern. The gametophyte (sexual generation) is so small that it is inconspicuous. Follow the diagram from left to right for a complete understanding of the life cycle as it manifests itself.

Description and life history of a fern. The fern plant grows from the tip of an underground stem called a *rootstock* or *rhizoid.* Each leaf or *frond* has a slender stem with *leaflets,* or *pinnae* (pĭn′nē), distributed along the sides. Such a leaf that is made up of leaflets is said to be *compound.* In general, the roots of a fern are comparatively smaller and less branched than those of a seed plant. If we examine the undersurface of the leaves of a mature fern, we shall find a number of little brown spots called *sori* (sō′rī). These are made up of many sporangia, or spore cases, each of which contains numerous spores. When the spores mature, they are shed and afterward germinate. Each spore develops into a small flattened, heart-shaped thallus, or gametophyte, called a *prothallium* (prŏ-thăl′ĭ-*ŭ*m). Colorless rhizoids form on the underside and near the smaller end of the prothallium. They hold the prothallium in place and absorb water and other materials from the soil. Sex organs also develop on the prothallium. The antheridia,

or male organs, usually develop between the rhizoids; the archegonia, or egg-producing organs, near the notch on the thicker and broader part of the underside of the prothallium. Sperms from the antheridia, by means of their *cilia* (sĭl'ĭ-ȧ), swim through water that collects on the prothallium. Finally a sperm reaches the neck of an archegonium and passes down to unite with the egg at its base. The zygote that results from this union is the first cell of a sporophyte. From this sporophyte, through cell division, an *embryo* develops. The prothallium at first furnishes food for the embryo. Later, however, the embryo develops a root which pushes into the ground and a leaf which grows upward. Thus a *new plant* forms which can draw water and other materials from the soil and manufacture its own food. When this plant becomes mature, sori develop on its leaves, and the life cycle is complete. As in the bryophytes, there has been an alternation of a gametophyte generation with a sporophyte generation.

A summary of the life cycle of a fern. The life cycle of a fern may be summarized as follows: The spore from a mature fern plant (sporophyte) germinates in the soil and forms a prothallium (gametophyte). Sex organs develop on the prothallium and produce male and female gametes. These unite to form a zygote which grows into a large leafy fern (sporophyte).

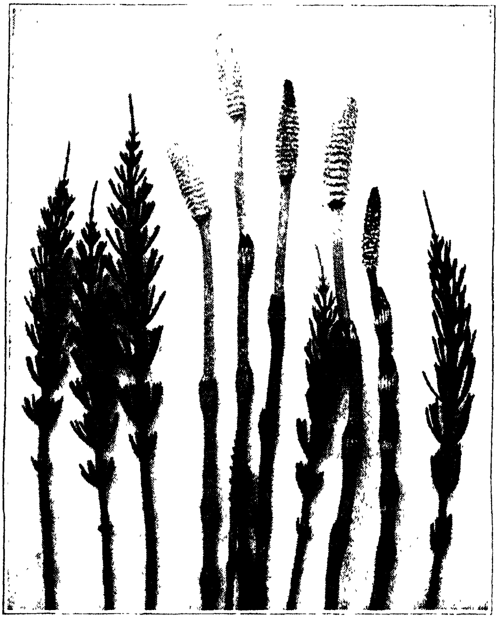
Ferns also multiply vegetatively[1] from their branching rootstocks, and some, like the walking fern, produce new plants from the tips of their leaves when these tips come into contact with the soil.

Horsetails

Plants that resemble horses' tails. Both the ferns and the *horsetails* are remnants of an ancient phylum that once was much more abundant than now. Fossils in coal mines, for example, indicate that during the coal-forming period the ancestors of horsetail plants were as large as trees and were widely scattered over the earth. Today, however, although a few tropical species are rather large, the horsetails are usually less than three feet tall. They grow in abundance in moist

[1] **Vegetative propagation occurs when new plants arise from stems or leaves.**

REPRESENTATIVES OF AN ANCIENT GROUP OF PLANTS—THE HORSETAILS



Courtesy Cleveland Museum of Natural History

This plant gets its name from its bristly appearance, suggestive of a horse's tail. Surprisingly, in view of its name, it is poisonous to horses when eaten.

places, as beside streams, on lake shores, and in marshes; and certain dwarfed species grow in dry places, as along railway embankments.

In appearance horsetails bear little resemblance to ferns. They are readily recognized by their upright stems and scaly leaves, which occur in *whorls* at the joints of the stems. There is no chlorophyll in their leaves; consequently food making is carried on in the stems. The horsetails are sometimes called scouring rushes because pioneer women used them to scour pots and pans. They were good for this purpose because of the silica in the epidermis or outer tissue.

The Club Mosses

Miniature descendants of giant ancestors. The low, trailing *club mosses* are perhaps the most ancient group of pteridophytes. Fossils show that during the coal-forming period they were among the largest plants of the forests. Today, however, they have slender branching stems and small scalelike leaves. The larger species are found in the northern woods, and the more delicate forms abound in the tropics. Some of the delicate types are also grown in greenhouses for decorative purposes.

THE NOBILITY AND ROYALTY OF THE PLANT KINGDOM—THE SPERMATOPHYTES

General characters. The *spermatophytes* are distinguished from all the other phyla by the fact that they bear seeds. They make up the most important phylum of the plant kingdom, including several hundred families. Among the most common families in America are the *grasses, lilies, pines, oaks, legumes, roses, mustards, mints,* and *orchids.*

The stems of all seed plants have an outer covering that protects the underlying cells. In herbs and young stems of trees and shrubs the outer layer of cells is called the *epidermis.* In older trees and shrubs the protecting layers are called *bark.* As in leaves, tiny openings, or *stomata* (stō′mȧ-tȧ), in the epidermis permit an exchange of gases between the air and the inside of the young stems and leaves. Gas exchange in older stems takes place through structures called *lenticels.* Most spermatophytes have extensive root systems for absorbing water from the soil and elaborate systems for transporting foods and water throughout their structures. All of these characters combine to make the spermatophytes the most hardy and successful of land plants. They are divided into two subphyla: the *gymnosperms* (jĭm′nō̇-spûrmz) and the *angiosperms* (ăn′jĭ-ō̇-spûrmz), each of which we shall now consider separately.

The Gymnosperms

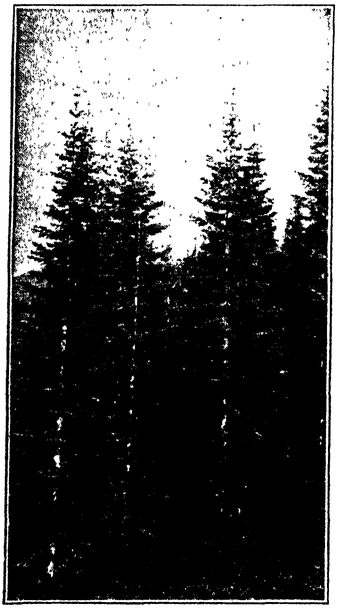
Plants with naked seeds. There are four orders of *gymnosperms,* the most important of which is made up of *conifers* (kō′nĭ-fẽrz) (cone-bearing plants). We find the largest and oldest living plants among the conifers, most of which are trees. They are generally distributed from the subtropics poleward as far as trees of any kind grow. While some of the conifers of the United States belong to the *yew* family, most of them belong to the *pine* family and include such trees as the pine, spruce, hemlock, and juniper.

Conifers differ from the oak, maple, and other similar trees in that most of them are not *deciduous* (dē̇-sĭd′ū̇-ŭs); that is,

they do not shed their leaves annually. In fact, with the exception of the larch and the bald cypress, the same leaves remain on the trees from three to ten years. This accounts for the name *evergreen* which is commonly applied to most of the trees of this type.

The leaves of most conifers, as those of the pine, spruce, and larch, are needle-like; those of the juniper, bald cypress, and arbor vitae are scalelike; while those of the fir, hemlock, and yew are flat and narrowly oblong. The needles of all conifers in the United States occur singly upon the stems except those of pines and larches, which occur in clusters. Because of their small surfaces and their heavy protecting cells the leaves are able to resist wide variations in temperature and moisture.

A GROUP OF CONIFERS OR WHITE FIRS



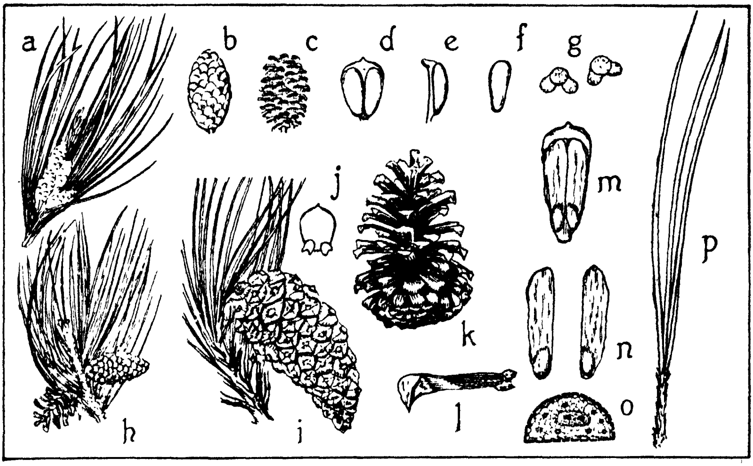
Courtesy United States Forest Service

The shape of the white fir is typical of that of all evergreens.

Life history of the pine. The pine, which is probably the best known of the conifers, nicely illustrates the life history of conifers. It bears two kinds of cones: (1) small short-lived structures, called the *staminate* (stăm′ĭ-nāt) or male cones, which produce *pollen;* (2) larger structures called the *ovulate* (ō′vū̆-lāt) or female cones, which bear *ovules.*[1] The small staminate cones appear in the spring of the year, at the base of new shoots on the ends of the branches. These cones are made up of many *stamens,* each of which bears two sacs filled with pollen grains. In late spring the *pollen sacs* burst open and the pollen is scattered by the wind. Sometimes so much pollen appears that it forms a yellow coat over the soil and near-by objects.

[1] Ovules are structures which finally become seeds.

THE PARTS OF A PINE SEED



In the illustration above are shown the following parts of the pine which are essential to food manufacture and reproduction:

a. Branch bearing staminate cone
b. Staminate cone, closed
c. Staminate cone, open
d. Stamen, underside
e. Stamen, side view
f. Pollen sac
g. Pollen
h. Branch bearing ovulate cone
i. Ovulate cone, closed
j. Ovulate scale bearing ovules
k. Ovulate cone, open
l. Ovulate scale, side view
m. Ovulate scale, upper side
n. Winged seeds
o. Cross section of leaf
p. Bundle of leaves

The ovulate or female cones appear about the same time as the staminate or male cones. They develop on the tips of the youngest branches, two or three usually forming rather close together. At first the ovulate cones are small green structures consisting of fleshy scales arranged about a central stalk, but later they become larger and their fleshy scales harden. On the upper surface of each scale are two cavities, each containing a spore case which, together with a megaspore, is known as an ovule. In the late spring the ovulate cones stand erect with their scales spread apart in such a way as to catch some of the pollen being released. When a pollen grain drifts in between two of the scales, it lodges near the *micropyle* (mī′krŏ-pīl), a tiny opening into the ovule. The scales then close and the cone droops downward, thus protecting the ovule from the rain and other unfavorable conditions.

A *pollen tube* develops from the pollen grain and grows from the micropyle down through the tissues of the ovule to the archegonium. Two sperm nuclei pass down the pollen tube. Then the tube bursts, and one of the sperm cells unites with the egg in the archegonium and fertilizes it. The fertilized egg, now known as a zygote, begins to grow by the process of cell division and forms a miniature plant. Thus the ovule after fertilization develops into a seed ready to produce another plant.

SCALY CONES OF THE LONGLEAF PINE

The conifers may be recognized by the fact that their fruits are scaly cones. Their needle-like leaves are commonly evergreen. Two exceptions to this are the bald cypress and the larches, which shed their leaves. (See page 591.)

In late autumn or winter the ovulate cone dries out and releases its seeds. In some pines the seeds have small and very delicate wings by means of which they are carried away by the wind. Finally they settle on the ground and, if they happen to alight in a favorable place, begin to grow. It usually takes two or three years for a pine cone to mature and bear seeds.

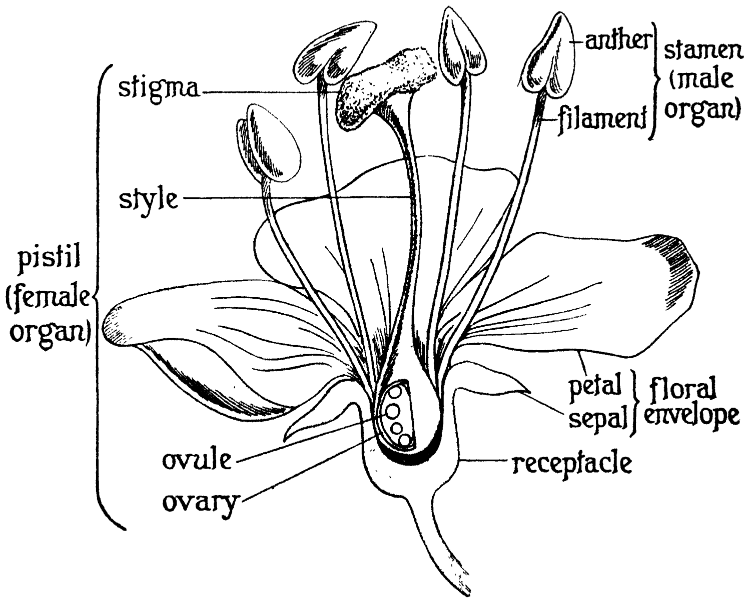
Now we can understand why the conifers are called gymnosperms. It is because their seeds are not inclosed in a sac or ovary. The word *gymnosperm* means "naked seeds." (See page 591.)

The Angiosperms

The plants with inclosed seeds. Although fossils indicate that the *angiosperms* are the latest plants to appear upon the earth, they are the most highly developed today. Furthermore, they lead in numbers, being represented by about one hundred forty thousand species, including *herbs, vines, shrubs,* and *trees*. They range in size all the way from minute forms to

gigantic trees. Their outstanding feature is that most of them produce *flowers* as organs of reproduction; consequently they are known as the *flowering plants*. They differ from the gymnosperms in that their seeds are inclosed in ovaries as shown in the following illustration.

A TYPICAL FLOWER SHOWING PARTS



The flower is the organ of reproduction in angiosperms. Its primary purpose is to produce seeds. The stamens produce pollen, each grain of which contains a male nucleus. The pistil produces ovules, each of which produces an egg nucleus. The sperm or male nucleus fertilizes the egg nucleus. The fertilized egg gives rise to a seed. Some plants are self-pollinating, but others must be cross-pollinated. (Diagrammatic)

The general structure and function of the roots, stems, and leaves of angiosperms are presented in Unit Six, and their reproduction is discussed in Unit Eleven. At this point, then, we shall consider only their flowers and some of their families of special interest. An outline of typical reproduction among the angiosperms is given on the following page. A more detailed explanation is given in Unit Eleven.

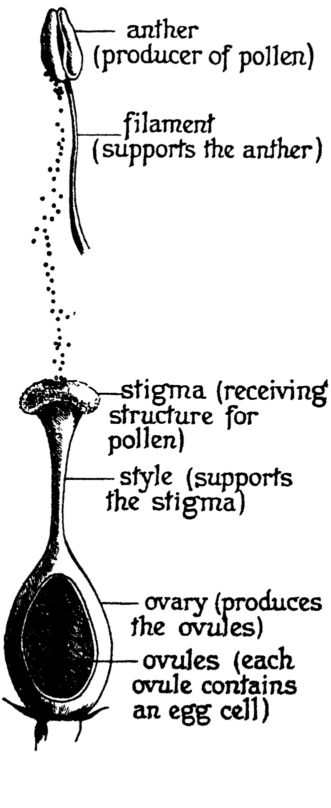
The Organs of a Flower

A. Floral Envelope

1. *Sepals*—The outermost leaflike parts that cover the unopened flower. Taken collectively they are called the *calyx.*
2. *Petals*—The inner leaflike structures that are usually brightly colored. Taken collectively they are called the *corolla.*

The purpose of the floral envelope is to protect the essential organs of the flower and to attract insects. In some species of angiosperms the petals are missing, and in others both the sepals and petals are missing.

FLOWER ORGANS ESSENTIAL TO REPRODUCTION



B. Essential Organs

1. *Stamen*—The part that produces pollen, within which sperm or male cells originate
   - *Anther*—Part of stamen that bears the pollen
   - *Filament*—Part of stamen that supports the anther
2. *Pistil*—The organ that produces ovules, within which egg cells originate
   - *Stigma*—Receiving structure for pollen
   - *Style*—Part of pistil that supports the stigma
   - *Ovary*—Part of pistil that produces the ovules
   - *Ovule*—Sac that contains an egg cell

Pollen is transferred from the anther to the stigma, after which a sperm unites with an egg in an ovule. This union forms a zygote which develops into an embryo or a miniature new plant. A ripened ovule with its embryo is called a *seed.* Thus both stamen and pistil are essential to reproduction.

Some families of angiosperms. The plants in the subphylum angiosperms are so numerous that it would require several seasons to become acquainted only with those that live about us. Consequently our study will be limited to an understanding of the characters of some of the more important families and ways of recognizing some of the more important plants of these families. The angiosperms are divided into two great classes: the *monocotyledons,* which have one *seed leaf* (*cotyledon*) in the embryo, and the *dicotyledons,* which have two seed leaves (cotyledons). We shall study monocotyledons first. (See Unit Six, pages 221–225, for a complete statement of the characteristics of monocotyledons and dicotyledons.)

THE KING OF CROPS—CORN

Courtesy Illinois Agricultural Experiment Station

The staminate flower is the tassel, and the ear and silk form the pistillate flower, the part which carries the ovules. The tassel produces pollen. The seeds, or kernels, are used in making meal, breakfast foods, oil, and various other products.

Plants with One Seed Leaf Monocotyledons

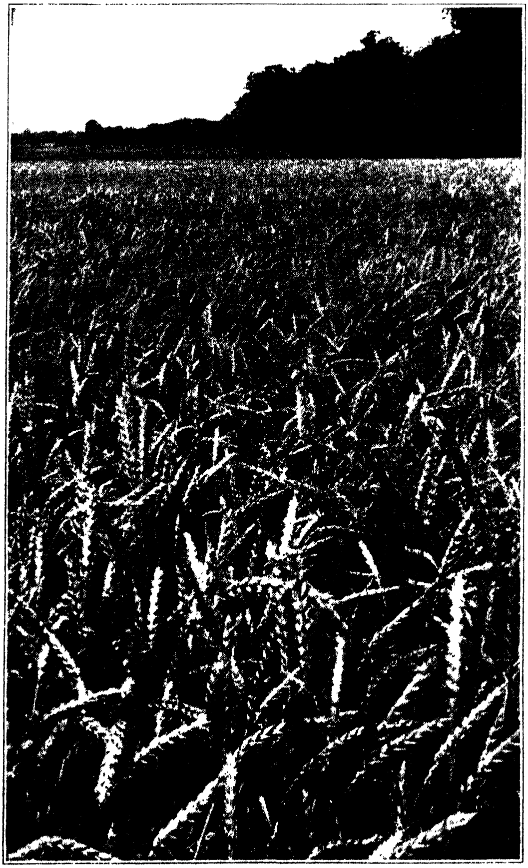
There are about forty-five families of *monocotyledons.* Most of the species, however, are found in four families: *grass, palm, lily,* and *orchid.* These families are important not merely because they contain many plants but because they furnish much food and add to the beauty of nature. Therefore we should learn to know them well.

The valuable grass family. The most important food plants in the world belong to the grass family. We should scarcely

know how to get along without wheat, corn, oats, barley, rye, rice, and sugar cane, to say nothing of the grasses that furnish food for domesticated animals.

Certain members of the grass family, known as *cereals*, are grown primarily for their seeds. Of all these members, wheat is probably the most valuable. It ranks first in production in the United States and is one of our largest agricultural exports. It is grown in various parts of the country, but thrives best in the North Central states.

FLOUR IN THE MAKING



This picture shows a field of wheat ready to be cut and threshed. The head on each stalk contains a number of seeds which will be removed in the threshing. Later the seeds will be taken to a mill and ground into flour.

Corn has often been referred to as the king of crops. It is a native of America. In fact, the Indians cultivated it before the white man came. Corn still seems to grow best in America, where four-fifths of the world's supply is produced. The ears, containing the grains, or kernels, are the most important part of the plant. These kernels are used as food for domesticated animals

as well as for man himself. Other parts of the plant are also used, forming the raw material for more than a hundred products, such as artificial silk, cellophane, and paper.

Rice is the principal food of nearly half of the people of the world. Although it is grown largely in China, Japan, India, and other oriental countries, it is also grown in our Gulf states and in parts of tropical America. Rice requires a moist soil that can be flooded at frequent intervals.

SUGAR IN THE MAKING

It is hard to believe that sugar cane, a member of the grass family, sometimes reaches a height of twenty feet. It provides a juice from which sirup and cane sugar are made.

Sugar cane is used for making sugar. It is a subtropical grass suited to cultivation in Cuba, Puerto Rico, Hawaii, the Philippines, some of our southern states, and other places where there is a rich soil and plenty of moisture. The cane plant somewhat resembles corn but has a much harder stem. This stem is the most important part of the plant, for it contains the sweet juice from which cane sugar is made.

The palm family. The palms, with their tall, unbranched stems and crowns of huge leaves at the summits, are always suggestive of tropical landscapes. Not all palms, however, are tall. Some are low and branching, and a few, like the rattans, are vinelike, often climbing to a height of one hundred fifty feet. Since there are many species of palms and their uses are greatly varied, we can consider only a few of the more important ones in this book.

The date palm is referred to in the Bible and other ancient writings. It is a very long-lived tree adapted to growth in hot, dry regions. From three to five hundred pounds of dates may be had from a large tree in a single season. Although the date palm is most common in Asia Minor and the tropics, it is also cultivated successfully in parts of Arizona and California.

THE CHIEF FOOD PLANT OF THE DESERT—THE DATE PALM

William Thompson

Clusters of dates hang from the lower part of the tree.

The coconut palm is more widely distributed than the date palm. It sometimes grows to a height of a hundred feet and bears a crown of huge feather-shaped leaves that curve downward. The fruit of this plant, the coconut, is very widely sold. The ovary wall of this fruit ripens into two layers: (1) the outer layer, or fibrous husk; and (2) the inner layer, which is hard and bony. The most important products of the palm are the nuts and oil.

If we were shipwrecked on a tropical island where there were coconut palms, we should have little to fear, because we could obtain all the necessities of life. The coconuts could be used

for "milk and meat"; the fibers and leaves could be woven into clothing and furniture; and the woody parts would provide shelter and fuel. That millions of people benefit from the palms is indicated by the following products made wholly or in part from them: building materials, clothing, fiber, sugar, starch, oil, wax, wine, resin, dyeing materials, and paper.

American palms. About fifteen species of palms are native to the United States. These are mostly of the characteristic fan-leaf type. One of the most common is the palmetto, which grows in the southern states. The Washington palm, a very interesting and rare species, grows only in the desert regions of Arizona and southern California. In addition to our native species, about two hundred species have been introduced from other lands and are now growing here.

Useful as well as beautiful — the lily family. Such beautiful plants as tulips, hyacinths, trilliums, lilies, and lilies of the valley are representative of the lily family. In addition to these ornamental plants, however, the family includes many food plants, such as onions, leeks, and asparagus. Nearly all members of the family are herbs with bulbs or rootstocks. One of the plants, the yucca, which is really a desert form, is successfully cultivated in city parks and gardens. (See the color plate of the lily family on page 339.)

More beautiful than useful — the orchid family. The greatest display of orchids is found in the tropics, where they are noted for their brilliantly colored and irregularly shaped flowers. Some of the tropical forms are highly prized as greenhouse plants. In temperate regions we find as a member of this family the pink lady's-slipper or moccasin flower, whose balloon-like blossom appears in June (see illustration on page 457). The orchids have little economic importance. The best-known product of the family is vanilla, which is obtained from the fruit of a species found in Mexico.

Plants with Two Seed Leaves — Dicotyledons

The *dicotyledons,* comprising more than two hundred forty families and about one hundred thousand species, include most

of the common flowering plants. The outstanding characteristics of this class, other than the number of cotyledons, are as follows: (1) generally five of each of the main parts of the flowers; (2) netted-veined leaves; and (3) vascular bundles arranged in a circle. These plants show a wide variation in size and manner of growth, ranging from small herbs that live but a single season to giant trees that live for centuries.

The tree families. It is not a difficult task for the average student to acquire a general knowledge of the tree families represented in American forests. Although these forests as a whole contain about fifty families and over six hundred species of trees, the average forest contains comparatively few. We have already studied the evergreens under the heading of gymnosperms. We shall now consider the trees that belong to the angiosperms. These are the broad-leaved trees that shed their leaves annually. In other words, they are said to be deciduous. Each tree family has certain characters that help in its identification. Among these characters are size and shape of leaves, nature of flowers and seeds, and structure of stem.

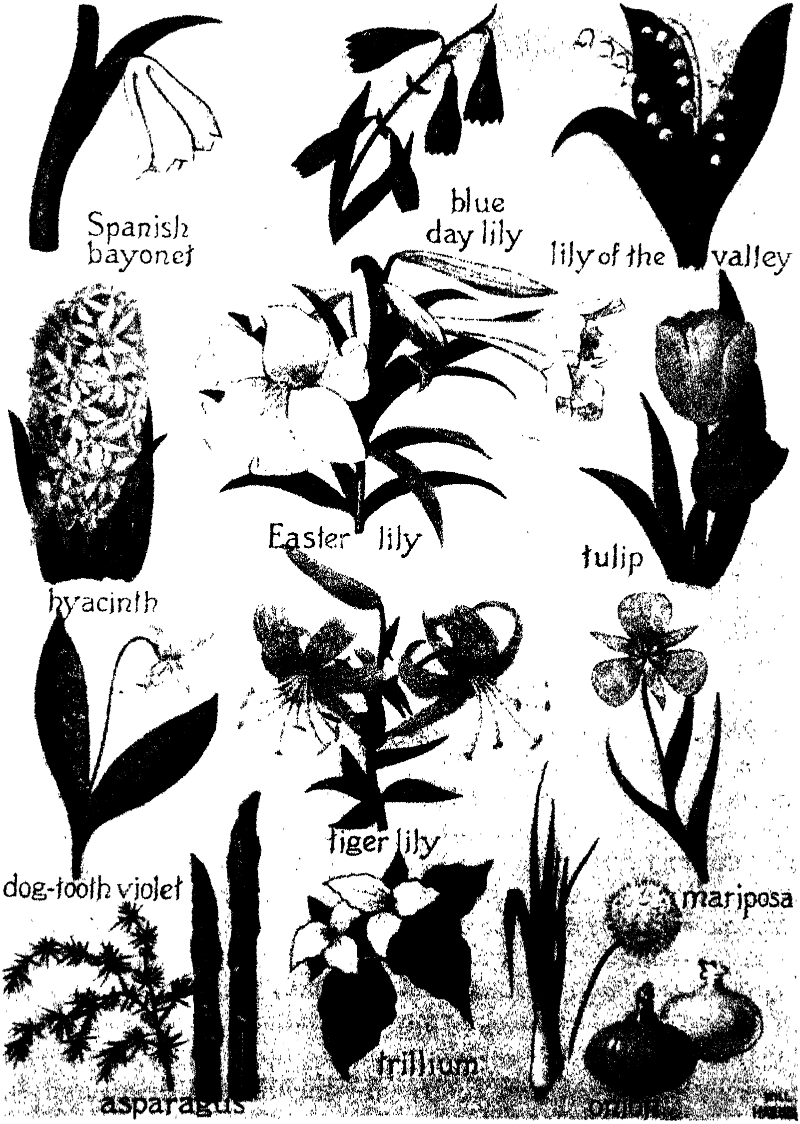
THE GRAY BIRCH AND ITS CATKINS

Courtesy General Biological Supply House

The catkins are the flower clusters or reproductive organs of the birch. Such structures are also common to certain other trees as willow, cottonwood, and alder.

Deciduous trees are often referred to as *hardwoods*. They include such common trees as the oak, elm, birch, walnut,

MEMBERS OF THE LILY FAMILY



Courtesy *World Book Encyclopedia*

These drawings show that the lily is a very broad and interesting family.

maple, hickory, and beech. The willow and poplar, however, which are also deciduous, have soft wood. Most deciduous trees have simple and usually inconspicuous flowers. Some of them, however, such as the tulip tree, magnolia, linden, locust, and buckeye, have very conspicuous and beautiful flowers. Others, such as the birch, willow, cottonwood, and alder, have flower clusters known as *catkins*. In the willow the *staminate* or male flowers and the *pistillate* or female flowers are usually produced on different trees.

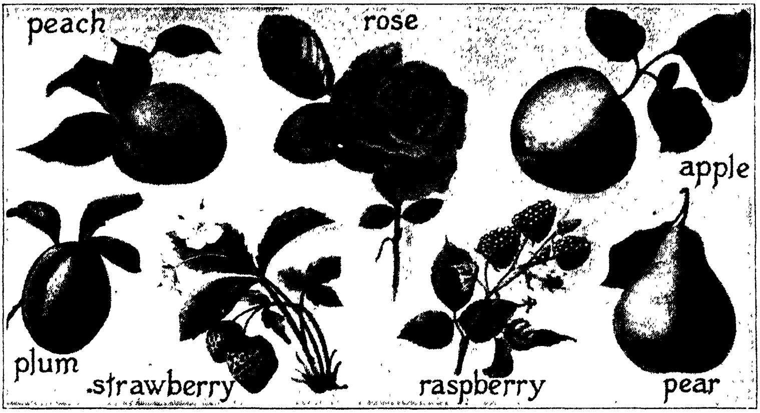
Only one-fourth of our lumber comes from hardwoods, the rest coming from evergreens. About half of all the hardwood lumber comes from the oak tree alone.

Sharp-tasting plants — the mustard family. The mustard family includes many edible plants, of which the best known are mustard, cabbage, turnip, radish, and cress. The family is also abundantly represented in waste places by such weeds as shepherd's purse, yellow mustard, and wild radish. Its members are characterized by a watery juice with a biting taste, alternate leaves, crosslike arrangement of the four petals in the flower, six stamens, and a distinctive *pod*. It is interesting to note that our cultivated cabbage has been produced from a small wild species, and that from it have been developed such well-known vegetables as cauliflower, kohl-rabi, collards, Brussels sprouts, and broccoli.

The legume family. The legumes (lĕg′ūmz) have been named from their peculiar fruits or pods (legumes) that contain the seeds. The best-known legumes are the peas and beans. The flower of the common sweet pea, with its one large upper petal, its two lateral winglike petals, and its two lower petals that surround the stamens and pistil, is typical of the family.

The legume family is a very useful one. Among its various plants the following should be mentioned: the sweet pea and wistaria for their flowers of fragrant odor; the common locust for its timber; the clovers, alfalfas, soy beans, and cowpeas for pasturage and their soil-enriching qualities; and the peas, beans, and peanuts for their seeds, which serve as the "lean meats of the vegetable kingdom."

USEFUL AND BEAUTIFUL MEMBERS OF THE ROSE FAMILY



Courtesy *World Book Encyclopedia*

These drawings show the great differences that exist in the rose family.

The rose family. Because of its name we are likely to think the rose family is important only for its beautiful flowering plants. Such, however, is not the case, as it includes also many trees and shrub fruits. The flowers of the rose family have five sepals, five petals, and many stamens. The fruits of the cultivated plants, as well as of some native plants, are fleshy and in many species are not only edible but delicious. These are usually classed under three heads:

1. *Aggregate fruits*—strawberries, raspberries, blackberries
2. *Stone fruits*—peaches, apricots, plums, cherries
3. *Pome* or *core fruits*—apples, pears, quinces

A widely distributed family—the composites. Nearly one-tenth of all the seed plants are included in the composite family. Some of the most common and widely distributed of these plants are the sunflower, dandelion, daisy, goldenrod, aster, chrysanthemum, and the troublesome ragweed. Members of the composite family may be recognized by the heads (clusters) of small flowers that have the appearance of a single blossom, as, for example, the ordinary sunflower.

FLOWERS OF THE CALICO BUSH

The mountain laurel, a member of the heath family, is often called the calico bush because of its handsome pink, white, or purple flowers. It grows largely in the eastern and southeastern part of the country.

Other dicotyledons. We shall complete our study of dicotyledons by considering a few other families that are commercially important. The *mint* family, for instance, gives us many of the herbs which are themselves valuable and from which are derived such oils as peppermint, pennyroyal, spearmint, thyme, lavender, rosemary, and horehound. The *potato*, or *nightshade*, family contains the tobacco plant, as well as such familiar garden plants as the potato, tomato, and pepper. The *heath* family includes such berries as cranberry, huckleberry, and blueberry, and such other important plants as mountain laurel, azalea, wintergreen. heather, arbutus, Indian pipe, and rhododendron.

Problem 4. What is there of interest in the animal groups?

We have now completed our study of the classification of plants and are ready to consider the classification of animals. In this study we shall begin with the lowest forms of life and end with the highest. In other words, we shall study the groups in the order listed on the following page.

Countless Unseen Water Inhabitants — the Protozoans
Animals with Bodies Full of Holes — the Porifera
Animal Flowers of the Sea — the Coelenterates
Worms and Their Ways
Scavengers of the Sea — the Echinoderms
Soft-bodied Animals — the Mollusks
The Largest Group of Living Things — the Arthropods
The Highest Group of Living Things — the Chordates

COUNTLESS UNSEEN WATER INHABITANTS THE PROTOZOANS

As we look into a pond of stagnant water, we may little suspect that it contains billions of interesting animals. If we take a drop of water from the pond, however, and examine it under a microscope, we shall certainly be surprised. We shall find the water teeming with life, especially with thousands of *single-celled* animals called *protozoans.* As we look at these animals, we shall find that they swim, capture food, defend themselves, and reproduce their kind. In short, we shall be amazed at all that takes place in the invisible world and once more shall appreciate the great value of the microscope in our study of life.

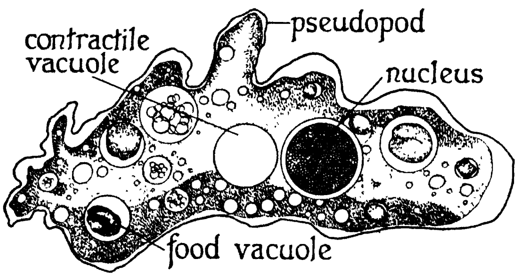
The protozoans are found not only in ponds, but also in streams, lakes, and seas, and some are found even in the blood stream and intestinal tract of larger animals. In all, there are approximately ten thousand known species and doubtless many more yet to be discovered. The protozoans reproduce very simply. The most typical method is a division of the parent cell into two individuals. The process takes place either by amitosis or by mitosis. The general characteristics of protozoans, as you will recall, are given in Unit Two.

Our lowliest animal — the amoeba. Among the inhabitants of a single drop of pond water we shall probably find one of the simplest forms of animal life, the amoeba. Upon closer examination we shall see that this is a tiny, shapeless, jelly-like mass of protoplasm. At times the mass may be more or less spherical

in shape, and again it may bulge out into projections called "false feet," or *pseudopods* (sū′dô-pŏdz). It is by thrusting out the pseudopods and flowing into them that the amoeba moves from place to place.

The amoeba employs a very interesting means of getting food. It does this by wrapping its body around small particles, such as microscopic plants, diatoms, bacteria, and smaller protozoans. The food is then engulfed in a space called the *food vacuole,* from which it is absorbed directly into the body. It is next rearranged and circulated by *protoplasmic movement,* after which it becomes living substance. (See Unit Two, page 76, for the meaning of protoplasmic movement.) Oxygen is absorbed through the wall of the cell. As the food is burned or *oxidized, waste products,* such as *carbon dioxide* and *urea,* are formed. These are excreted mainly through the surface, but they are also removed by means of the *contractile vacuole.* Thus, without teeth, stomach, or intestines, the simple amoeba carries on the processes of eating, digestion, absorption, and excretion.

ONE OF THE SIMPLEST ANIMALS
THE AMOEBA



The amoeba is about 1/100 part of an inch in diameter. It can easily be seen, however, under the low power of a microscope, showing a constant streaming movement.

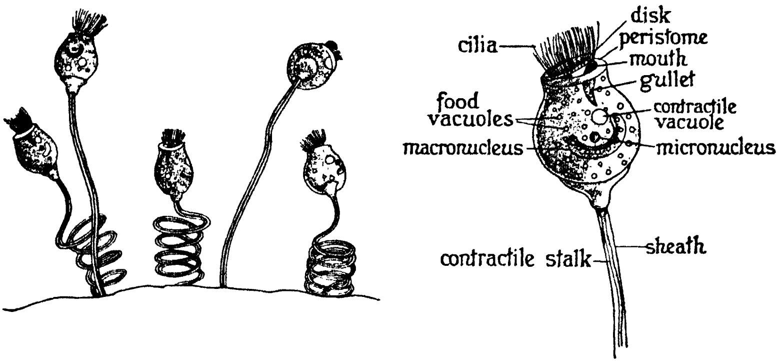
An animal that moves like an automobile piston—the Vorticella. One of the most interesting protozoans is the Vorticella (vôr-tĭ-sĕl′*ȧ*). If we look at this strange little animal under the microscope, we shall find that it lives in a colony along with many other animals of its kind. It consists of a headlike part and a stem.

The Vorticella puts on a very interesting show under the microscope. Five or ten separate animals of the colony arrange themselves in a straight line and jump up and down

like the pistons of an engine. As one group goes up, another goes down. The whole scene is very fascinating.

The food-getting process of the Vorticella is a little more complex than that of the amoeba. The Vorticella catches its

A COLONY-MINDED PROTOZOAN—VORTICELLA



The performance of Vorticella under the microscope is indeed fascinating. This is due to the rhythmic contractions and extensions of the contractile stalks.

food by the *contractile stalk* as it raises during the action just described. The food is washed by *cilia* into a sort of mouth or *gullet* and then on into a food vacuole, where it is digested. This vacuole may then be pushed to another part of the body as a new vacuole is formed.

Another species of protozoans, the Paramecium, is discussed in detail in Unit Two. Reference is also made to the interesting stentor.

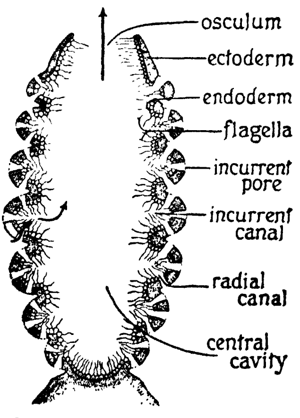
Could we run the world without the protozoans? If all the protozoans in the world were suddenly to become extinct, what would happen? This question, of course, is difficult to answer, because life seems to have a peculiar way of readjusting itself. Protozoans are eaten by other animals as food. These animals are eaten by still higher forms, and so on up the animal scale. Protozoans also help to prevent the spread of dangerous bacteria by feeding upon them. Thus we may safely say that protozoans have an important place in the world and that we need them to help maintain the balance of life.

The beginning of colonial life in the animal kingdom. Even the protozoans seem to realize that it is better to live together than alone in the world. Some of them are so closely associated that they function almost as a single organism.

ANIMALS WITH BODIES FULL OF HOLES
THE PORIFERA

The *Porifera,* or sponges, are animals with a cylindrical body, one end of which is attached to some object, the other being open. The body wall contains many *pores* connected with a central *body cavity* by *canals.* The body is supported by a skeleton or frame made of limy or glasslike *spicules* (spĭk′ūlz), or horny fibers. It has two distinct layers of cells, an internal or digestive layer, called the *endoderm,* and an external or protective layer, called the *ectoderm.* Between these two layers is a jelly-like substance containing many amoeba-like *wandering cells.* The ectoderm contains numerous openings, or *pores.* The drawing at the left gives a better understanding of the structure of this animal.

SECTIONAL VIEW OF A SPONGE

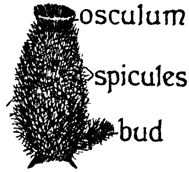


Water containing minute food particles enters through the incurrent pores and is carried out through the osculum.

How the stationary creatures eat. It is hard to believe that such a lifeless appearing animal as a sponge can take in food, digest it, and carry on other life processes, but it does. The endoderm possesses long appendages called *flagella* (flȧ-jĕl′ȧ) that wave back and forth. This movement causes a current of water to enter the body cavity through the canals and to pass on out again through the open end, called the *osculum* (ŏs′kū-lŭm). Thus food particles are carried into the body. These are digested by the endoderm cells and by the amoeba-like wandering cells between the endoderm and the ectoderm.

How the sponges reproduce their kind. In the adult form sponges are incapable of locomotion, but this does not prevent them from carrying on reproduction. They reproduce both *sexually* and *asexually*. In the latter case buds are formed. These buds either separate from the parent and take up their own existence, or they remain attached to the parent and form a group of individuals. In their sexual reproduction both male and female cells originate in the same individual. This condition is known as *hermaphroditism* (hẽr-măf′rô-dīt-ĭz′m). The sex cells, however, usually mature at different times; hence cross fertilization is necessary. Thus the male cell of one sponge fertilizes the egg cell of another. Then a free-swimming *larva* (immature stage) is formed which eventually attaches itself to a stationary object, such as a rock, and grows into a sponge.

EXTERNAL VIEW OF A SPONGE



The bud illustrates asexual reproduction.

Where sponges are found. Sponges are chiefly marine animals, although there are a few fresh-water forms. One of the most beautiful sponges to be found is the Venus's flower basket, which grows along the shores of the Philippine Islands. Most of our commercial bath sponges come from such places as the coasts of Florida, Cuba, the Bahamas, Australia, and the Mediterranean Sea.

ANIMAL FLOWERS OF THE SEA — THE COELENTERATES

No more interesting animals can be found than the *coelenterates*. Their appearance, structure, and reproduction are so strikingly unusual that they help give the sea a touch of grandeur and mystery. So closely do many of these animals resemble plants that when they are observed undersea they have the appearance of beautiful aquatic flower gardens. Their bodies are trunklike with a number of flexible appendages called *tentacles* (tĕn′tȧ-k'lz). They may be cylindrical, like the sea anemone, or baglike, like the jellyfish, but they are not porous. Some of them, like the sponge, are attached at one

CORAL GARDENS OF THE SEA

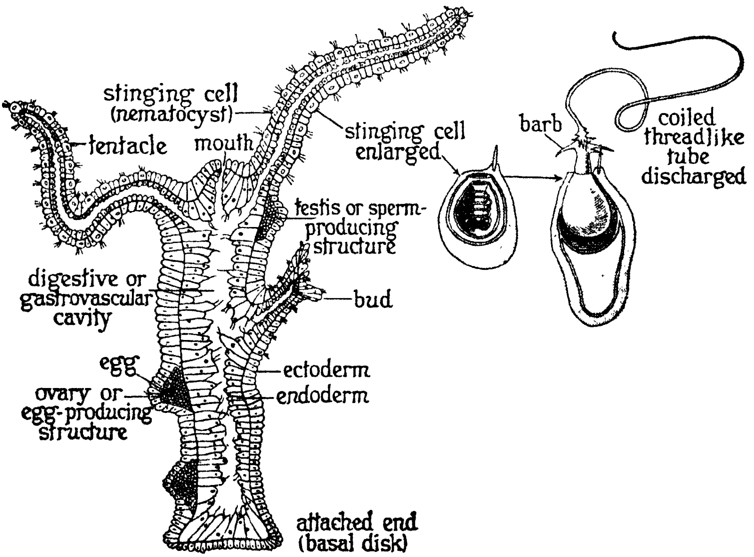
Courtesy New Wonder World

end and open at the other, but the open end serves as both mouth and vent. The mouth is surrounded by tentacles which perform certain sensory functions and assist in taking in food. The picture on the opposite page shows some of their interesting shapes and beautiful colors.

The Stinging Hydra

How the hydra "lassoes" its food. The hydra is the one coelenterate that is not a marine animal. It lives in fresh water and has a body similar to that of the sea anemone except that it is much smaller. In fact, it is only about a half-inch long and about as thick as a pin. Its tentacles and most of its

THE HYDRA AND ITS "LASSO"



How does the hydra capture an animal with its lasso cells?

body are equipped with numerous coiled threadlike tubes called *nematocysts* (nĕm′ȧ-tō-sĭsts′). The hydra uses these nematocysts for stinging tiny animals and paralyzing them with a poison. After the poisoning, it draws the victims into its mouth by means of its tentacles and uses them as food.

The central cavity of a hydra is lined with endoderm cells, each of which behaves in some respects like an amoeba. These cells send out projections that engulf and digest the food. Waste materials are discharged through the vent or open end of the body.

How the hydra reproduces. The hydra reproduces sexually and by *budding,* which is a method of asexual reproduction. It develops a swelling near the tentacles in which *sperms* form and a swelling near its base in which an *egg* forms. Thus the hydra is a *hermaphrodite* (hĕr-măf′rō-dīt), producing both sperms and eggs. Sometimes fertilization takes place within a single hydra, but cross fertilization is more common. After fertilization each egg breaks loose from the body of the parent and develops into a new hydra.

The Changeable Obelia

Polyp or jellyfish — which? Among all the creatures of the sea few are more interesting than the Obelia (ō-bēl′yȧ). This strange form of life lives as one type of creature in one generation and as another in the next. In one generation it is known as a *polyp* and looks somewhat like a plant. It

THE FIRST GENERATION

Courtesy *American Museum of Natural History*

In one generation the Obelia appears in the form of a polyp. This picture shows a number of polyps in a colony.

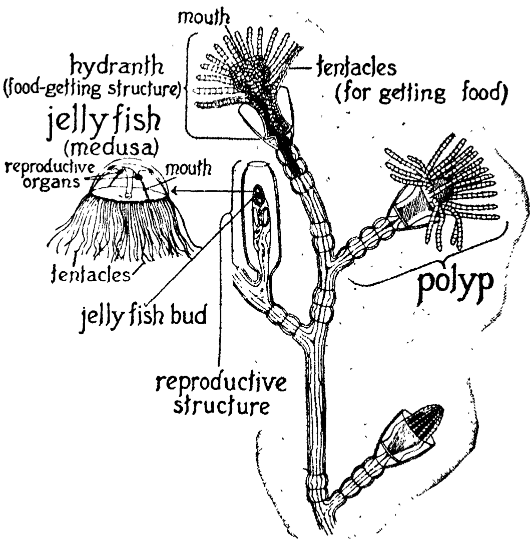
THE SECOND GENERATION

Courtesy *American Museum of Natural History*

In the second generation the Obelia appears as a jellyfish. It is so named because of its jelly-like body.

attaches itself to a rock or plant where it exists as a member of a colony. The entire colony resembles a branch of a tree. At the center is a stalk which holds the branches together. At the end of each branch is a bell-like projection supporting a cluster of tentacles. Some of the bell-like projections take in food for the colony. Others, known as *medusa buds,* are formed for the purpose of carrying on asexual reproduction.

THE LIFE HISTORY OF OBELIA



At the right is an attached Obelia colony consisting of a stem and branches (polyps) resembling those of an ordinary tree. At the left is a free-swimming jellyfish (medusa) developed from a jellyfish bud of the attached colony.

Now we are ready to consider the type of life in the next generation. When a medusa bud at the end of a branch of the polyp reaches a certain stage in its development, it breaks loose and floats away as a separate creature, called a *jellyfish.* This creature swims freely and looks like a tiny umbrella moving about. It looks and behaves so differently from a polyp that it is almost impossible to believe that it came from one. It reproduces sexually, producing sperms or eggs, depending upon whether it is male or female. Fertilization takes place in the water, and the eggs hatch. Strange to believe, each jellyfish egg produces a polyp.

Thus the Obelia continues to exist as polyp and jellyfish. First it exists as one and then as the other. The polyp by asexual reproduction gives life to a jellyfish, and the jellyfish in

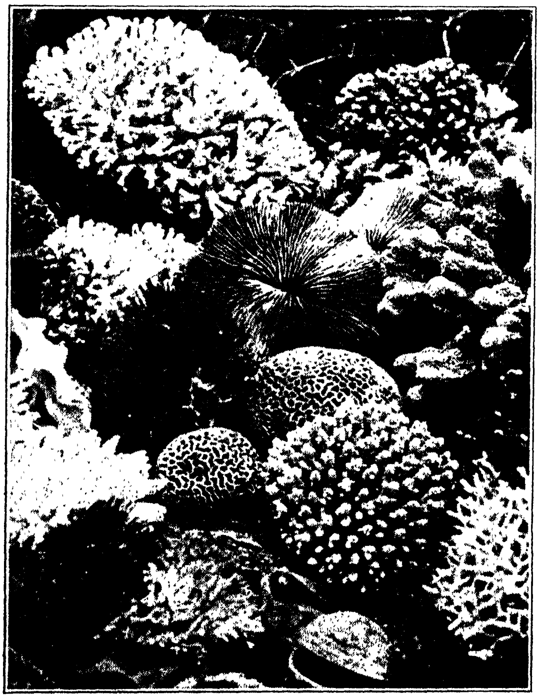
turn, by sexual reproduction, gives life to a polyp. The polyp remains stationary, attached to a stone or a plant, but the jellyfish swims about as a moving organism.

Corals—Animals Made of Stone

An Imaginary Trip to the Habitat of Coral Polyps

We are aboard a glass-bottomed boat near one of the islands of the Florida Keys. A guide suddenly announces that we are approaching the widely known submarine flower gardens and the zoo in which the animals are made of stone. We peer into the depths and marvel at the beautiful sea anemones and coral polyps that spread out below us. Interesting shapes, such as waving sea fans, colonies of organ-pipe, brain, and horn corals, and many rich colors, such as green, red, purple, pink, and blue, blend perfectly with the sea anemones to provide a real submarine garden.

TYPICAL CORALS



Courtesy *Nature Magazine*

The fantastic structures shown above are the supporting skeletons of many marine animals. The offspring remain attached to the parents, thus building extensive colonies.

The guide explains that a coral animal secretes a stony support about its base, inside which are its tentacles and baglike body. The buds through which the coral reproduces

ANIMALS THAT BLOCK THE PASSAGE OF SHIPS

This is a low-tide view of the Great Barrier Reef of Australia. Each coral colony contains hundreds of polyps united by a colored fleshy material.

itself remain attached to the parent. Thus after a period of time many stony animals that have not separated from their parents build great colonies and even form islands and reefs. Certain reef-building corals, so the guide tells us, thrive best in clear, deep water at an average temperature of 68° Fahrenheit. They do not thrive near the shore, where the water is muddy and warm. Consequently reefs usually appear a short distance from the shore, where they act as a breakwater to the dashing waves. Reefs may present a dangerous barrier to the passage of ships, as does the Great Barrier Reef of Australia, which is more than 1,100 miles long. In some regions, as in the Pacific Ocean, large islands have been built from skeletons of corals.

WORMS AND THEIR WAYS

Worms cannot be presented as a single group because they belong to four distinct phyla that vary widely in their characteristics. The common names for the four phyla are *wheelworms*, *flatworms*, *roundworms*, and *segmented worms*. The one characteristic common to all phyla of worms is a slender, elongated body which is bilaterally symmetrical or nearly so. This means that the two sides of the body are similar in shape. Thus every worm has an *anterior* or head end, a *posterior* or tail end; a top or *dorsal surface;* a bottom or *ventral surface;* and right and left sides that are similar.

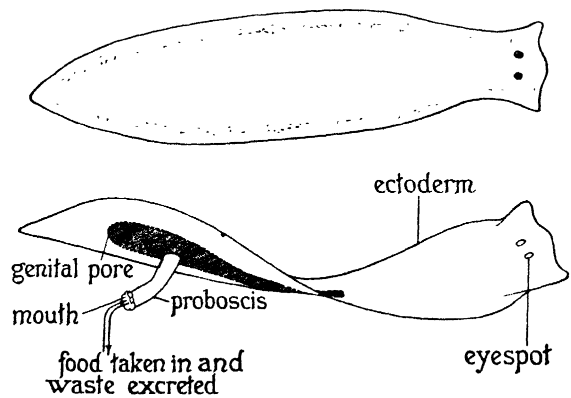
Worms with a Wheel-like Motion—The Wheelworms

The *rotifers* (rō′tĭ-fĕrz), or wheelworms, are microscopic in size, more or less cylindrical in shape, and greatly resemble protozoans. They have a digestive tract including an anterior mouth and a posterior vent. The mouth is lined with cilia. The name *wheelworm* comes from the wheel-like movement of the head, which is caused by the rhythmic action of the cilia. As a group the rotifers have no particular importance.

The Freaks of the Worm World—The Flatworms

The *flatworms* are commonly found in ponds, attached to stones and leaves. In one respect they are not so well developed as their cousins, the wheelworms, roundworms, and segmented worms, for they have but one opening into their

THE PARTS OF A POND FLATWORM

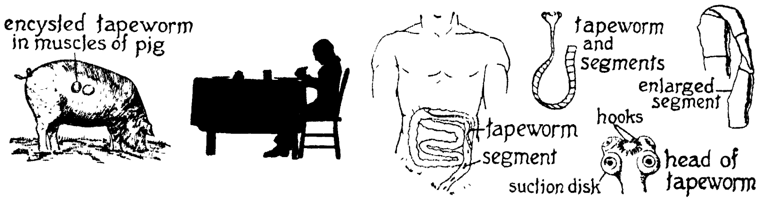


How does the digestive system of the flatworm resemble that of the coelenterates?

digestive tract. Thus they resemble the coelenterates in that they take in foods and excrete wastes through one body opening. In other respects, however, they differ from the coelenterates and are more advanced than any of their cousins. They have fairly complex bodies, for instance, possessing outer (ectoderm) and inner (endoderm) layers of cells and a middle layer (*mesoderm*) which contains muscles, reproductive

organs, a nervous system, a digestive system, and a crude excretory system. They have two eyes, but the eyes are so crude that it is doubtful whether they can use them for seeing. In general, flatworms can move easily and have the ability to crawl and glide about. Among the best known flatworms found in ponds are the Planaria (plȧ-nā′rĭ-ȧ).

THE LIFE STORY OF THE TAPEWORM



Brood cases, containing sperms and eggs, are eaten with grasses by an animal such as a hog. Man acquires the embryo by eating poorly cooked meat from the animal.

A flatworm that lives in the intestines — the tapeworm. Isn't it strange that, of all the places in which the tapeworm might live, it finds no better home than the intestinal tract of man? Such, however, is the case, the odd creature being carried into the body in undercooked meat. When we study the structure of the tapeworm, we find that it has no mouth or digestive tube of its own. This is not surprising, since it can absorb all the predigested food that it needs from the intestine of its host.

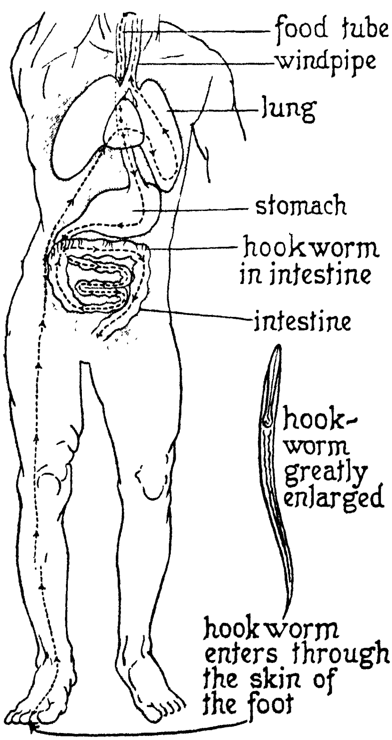
Once it finds its home the tapeworm attaches itself to the intestinal wall by means of *hooks* and *suckers* that extend from the *scolex*, or head of its body. It then divides into several segments, each of which is practically a worm in itself. In fact, it is by means of division into segments that the worm grows longer. As the segments divide they are pushed back from the head, making the tail segments the oldest ones in the body. Each segment produces sperms and eggs. The tail segments serve as brood cases for developing embryos, and later separate from the rest of the tapeworm. From time to time they are discharged from the body as a part of the intestinal excrement. Thus the brood cases are scattered, especially

in rural localities where sewage is not scientifically treated. Some of these brood cases are eaten with grasses by herbivorous animals, such as hogs. When the embryo in a brood case reaches the digestive tract of an animal, it bores its way through the wall of the intestine into the muscles and encysts itself. Danger of tapeworm then arises from eating undercooked meat.

WORMS WITH ROUND BODIES—THE ROUNDWORMS

Roundworms differ from flatworms in that they have a digestive tube with both a mouth and a posterior opening. Their bodies also contain *blood* or a *body fluid,* but strangely they have no circulatory system of *blood vessels* and *heart.*

AN UNUSUAL TRAVELER



The hookworm is especially dangerous because it can enter the body in several ways.

A worm that enters our feet—the hookworm. It is hard to believe that a worm would attempt to enter the body through the feet. The hookworm, however, does this very thing if it gets a chance. Sometimes it is carried directly into the digestive tract by food; if not, it attempts a more indirect route through the skin. Two means of protection suggest themselves: (1) the wearing of shoes and (2) the eating of sanitary food.

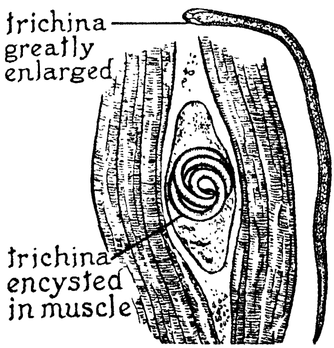
The larvae of the hookworm live in the moist soil of more or less tropical lands and are found in some of our southern states. They enter the body of man through the skin by way of the feet or some other exposed part. Once in the body they are carried by the blood stream

to the lungs. Here they burrow into the tissues, doing considerable damage. Finally, when mature, they make their way into the windpipe and on into the throat. Next they are swallowed and swept on into the intestine, where they attach themselves and begin sucking blood. Eggs are now laid and carried through the intestinal excrement into the soil.

That the hookworm is a serious pest may be realized from the fact that millions of people suffer from its attacks. These attacks result in a loss of blood and irritation of lung and intestinal tissues that cause weakness and listlessness in the victim. General impairment of health and even death may result.

Other roundworms. The gapeworm and trichina (trĭ-kī′nȧ) are other important examples of roundworms. The gapeworm, often called forked worm, attacks the windpipes of chickens and other birds, producing a disease called gapes. The trichina attacks the muscles of man. Its larvae usually get into the body through the eating of undercooked meat. An adult female frequently deposits as many as a thousand young embryos at one time. When these are born, they work their way into the muscles, where they cause degeneration of the tissues and a disease called trichinosis (trĭk′ĭ-nō′sĭs). The symptoms of the disease are intestinal pains, nausea, diarrhea, muscular pain, and stiffness.

A DANGEROUS PARASITE
THE TRICHINA



The photomicrograph shows the trichina encysted in muscular tissue.

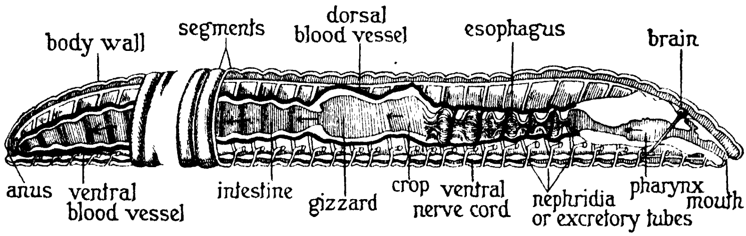
Worms with Segmented Bodies—The Segmented Worms

Recently when we studied the flatworms we found that they were divided into segments. These worms, however, as we recall, have no complete digestive tube, and each segment is largely complete in itself. *Segmented worms,* on the other hand, have a well-developed digestive tract with both anterior

mouth and posterior opening. The most common example of segmented worms is the ordinary earthworm or fishworm.

The story of the earthworm. The body of the earthworm is divided into many segments. Each segment except the

THE INTERNAL MECHANISM OF THE EARTHWORM



This is a diagrammatic representation of the internal parts of the earthworm. A section of the worm is omitted where the external segments are shown.

first three and the last contains four pairs of unjointed appendages called *setae* (sē′tē) or bristles. All the segments except the first three and the last contain paired excretory tubes called *nephridia* (nĕ-frĭd′ĭ-ȧ). Extending the full length of the body is a well-defined nervous system, consisting of a brain on the dorsal side and a ventral nerve on the lower side. Within each segment is a mass of nerve cells called a *ganglion* from which nerves extend in all directions. Most of the segments are separated by walls, but they are perforated by the intestine, nervous system, nephridia, and blood vessels. Reproductive organs are found in several of the segments near the anterior part of the body. The reproduction itself takes place through an exchange of sperm cells between two worms. The cells are stored away and used to fertilize the eggs when they are laid.

The earthworm that inhabits the soil of lawns and fields is a good example of the segmented type of worm. If we sprinkle a lawn before dark and examine it with a flashlight or lantern after dark, we shall be amazed at the number of earthworms that we find at the surface. Since they appear in this way, they are often called *night crawlers*. If we are quick enough, we may capture some of them before they crawl back into

the soil. We may also bring earthworms out of the soil by producing some form of vibration. For example, we may drive a stake into the soil and rub it across the top with a board. Some say that we may attract earthworms with music, but experimental evidence seems to show that they have no appreciation for music, even when it is well played.

SCAVENGERS OF THE SEA — THE ECHINODERMS

The *echinoderms* are unique in two respects: (1) they compose the only phylum of animals all families of which live in the sea; (2) they are so unfamiliar to us that no common English name has been given to them. The name *Echinodermata,* a Greek word meaning "spiny-skinned," seems well suited to most of the sluggish creatures. Although the echinoderms are comparatively uninteresting and unimportant in a commercial sense, they have a distinct value, as indicated by a noted biologist who says, "An ocean without echinoderms might become a putrid cesspool, since billions of them are constantly doing duty as scavengers."

There are five classes of echinoderms, including the *starfish, brittle star, sea urchin, sea cucumber,* and *sea lily.* The starfish, which perhaps is the best known of the classes, illustrates the chief characteristics of the phylum.

THE STARFISH

A spiny animal with five "arms." Although the starfish may have hundreds of *feet* attached to its five arms or *rays,* it cannot win many races, for it travels only about three inches a minute when going at full speed. Its movement comes from the passage of water through its *water-vascular* or *water-tube system.* At the end of its tubular feet are well-formed *suckers* by which it can firmly fix itself to any solid surface. These feet also serve as *organs of touch* and are constantly stretching out here and there and then retracting as the starfish carefully explores its immediate surroundings.

Let us examine the upper or dorsal surface of the starfish. The skin consists of hardened limy plates, and from it extend

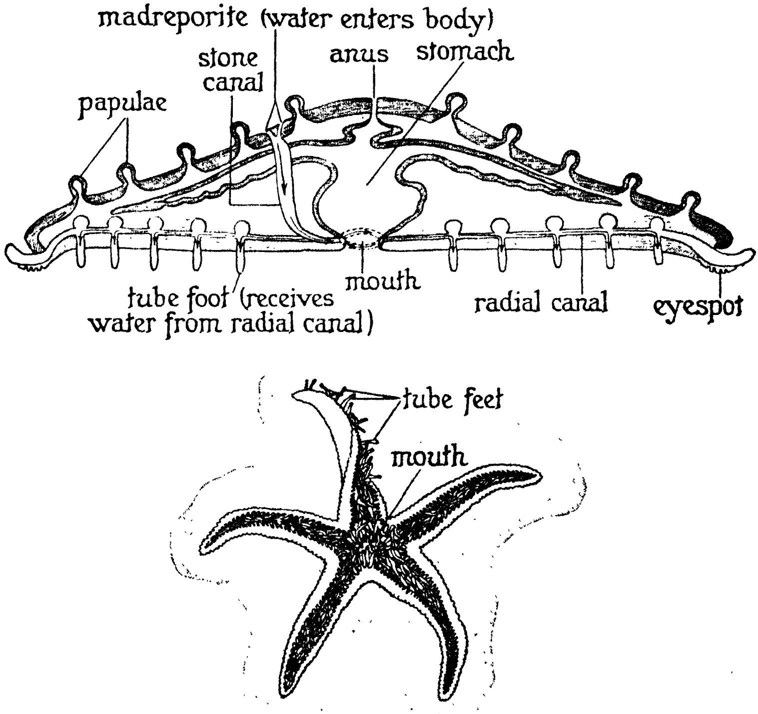
ECHINODERMS AT HOME

Meinhold Colored Animal Chart—Courtesy A. J. Nystrom & Company

Among the most interesting echinoderms in this picture are the spiny sea urchin at the upper left, the two starfish at the center, and the sea cucumbers at the bottom.

many *spines* of various sizes. Between two arms on the central disk is located an organ called a *madreporite* (măd′rê-pô-rīt). It is a wartlike, red and white structure that admits the water

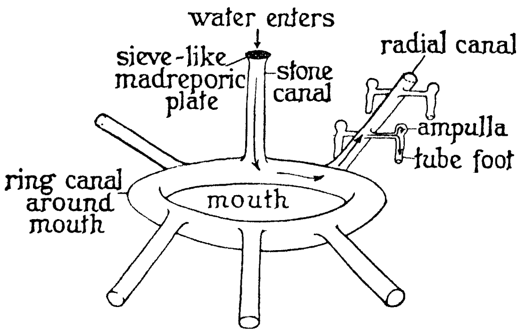
THE STARFISH AND ITS PARTS



The upper diagrammatic view through two arms of the starfish shows the parts of the digestive system and the water system. The lower view shows the undersurface (oral) and the numerous tube feet.

to the water-vascular system and also serves as a sieve for keeping out sand. The water-vascular system, shown on the following page, besides enabling the starfish to move about, also helps in circulation and respiration. Regular circulation, however, takes place in the body cavity and respiration through *papulae* (păp′ū-lē), outpushings from the body wall. At the tip of each arm is a sense organ somewhat like an eye,

WATER-VASCULAR SYSTEM OF THE STARFISH



Water enters the sievelike opening upon the top surface of the starfish. It passes into the ring canal around the mouth and is distributed by means of the radial canals to the feet. The contraction of the ampullae expels the water, and suctions are created in the tube feet, enabling them to adhere to the surface upon which the starfish is moving.

called an *eyespot.* Near the middle of the central disk is a small anal opening.

Dining with the starfish. It is interesting to watch a starfish in the act of devouring its prey, especially if the prey is too large to be taken directly into the stomach. It may seize a clam with its tube feet and place the victim directly under its mouth. This mouth is located at the center of the lower side of the central disk. Next it brings its arms or rays down over the victim somewhat as a person closes an umbrella. It then tugs away at the valves of the clam until they open. Its stomach literally turns inside out and presses between the valves, where it comes into contact with the soft body parts of the clam. It completely consumes the soft parts and leaves the shell empty. When it has finished with its victim, it has not only completed a meal but also has washed the dishes.

A STARFISH DINING ON AN OYSTER

Courtesy United States Bureau of Fisheries

The starfish may exert a steady pull upon the oyster or clam for as long as forty-eight hours. The muscles of the bivalve finally weaken and the shell opens.

The remarkable powers of reproduction and regeneration. Sperms and eggs are produced in separate starfish; that is, each has a definite sex. A pair of *ovaries* at the base of each arm or

ray in the female produces the eggs. A pair of *testes* located in the same position in the male produces the sperms. The eggs and sperms are discharged into the water. Sperms, by means of tail-like *flagella,* swim to the eggs, where fertilization takes place. (See the illustration on page 595 for the reproductive organs of the starfish.)

The starfish repairs bodily injuries and even reproduces by *regeneration.* If an arm is broken off, a new one grows in its place. A story is told of some angry fishermen who tore a starfish apart so that it would not destroy their oysters. They threw the pieces into the sea and thought they had accomplished their purpose. Soon, however, more starfish appeared, and the men repeated their performance. In due time there seemed to be more starfish than oysters. Little did the men know that every arm that retained a part of the central disk grew into a fully developed starfish capable of reproducing its kind.

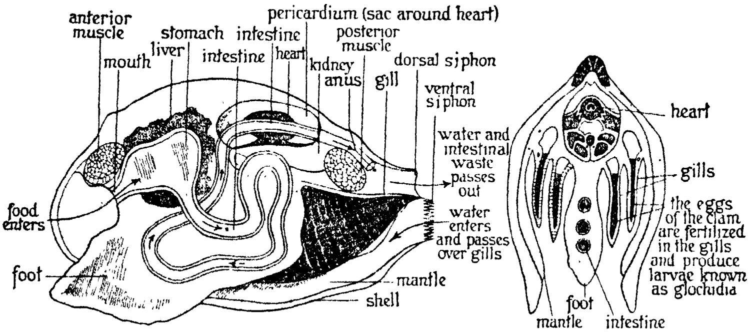
THE SOFT-BODIED ANIMALS—THE MOLLUSKS

The phylum of *mollusks* is very large and widely distributed, containing about sixty thousand living species occurring on land, in the sea, and in fresh water. Among the more important are the clams, mussels, oysters, snails, and slugs, as well as the squids and octopuses so often referred to in stories of the sea. The mollusks have soft, unsegmented bodies usually covered with shells, as illustrated by clams, oysters, and snails. Some of the mollusks, however, as slugs, octopuses, and squids, have no shells on the outside of their bodies. All species possess a part called the *foot,* which serves as an organ of locomotion, as anchorage, or as a weapon for capturing prey. According to the shape or position of the foot, all mollusks are grouped into three principal classes: (1) *Pelecypoda* (pĕl-ĕ-sĭp′-ō-dȧ), which means "hatchet-footed," represented by clams, oysters, scallops, and mussels; (2) *Gastropoda* (găs-trŏp′ō-dȧ), meaning "belly-footed," represented by snails and slugs; (3) *Cephalopoda* (sĕf-ȧ-lŏp′ō-dȧ), meaning "head-footed," represented by squids, octopuses, and cuttlefish.

Clams and Mussels

The "hatchet-footed" animals. Clams, mussels, and their near relatives, oysters and scallops, have shells of two pieces connected by a muscular hinge. Because of these structures

THE ODD MECHANISM OF A CLAM



This animal is truly one of nature's freaks. By following the arrows you will note that the intestine (food tube) not only passes through the animal's foot, but through the heart as well. The gills serve as a nursery for the larvae as they hatch from the eggs.

these animals are known as *bivalves*. For centuries they have played an important part in the life of man. They have great economic value as food, and have been popular in this country ever since the Indians taught the early Pilgrims how to dig clams and hold clambakes. It is surprising how many colorful expressions about the behavior or structure of clams have found their way into our language. The expression "a clammy feeling" has a real meaning if we but pick up a live clam. Likewise we can understand "tight as a clam" if we try to pry open the two parts of its shell covering.

Looking in on the clam. The common fresh-water mussels or clams may be easily procured for study if we dig into the sand or mud in and along streams. Each clam will be found buried with its anterior end pointing downward. Thus it would seem that a clam is most comfortable when it is standing on its head.

Two layers of *gills* lie on each side of the clam's body. At the posterior end of its shell are two openings called *siphons*.

The clam draws in water through one of these siphons and lets it out through the other. As this water passes over the gills, it gives off oxygen and takes up carbon dioxide and other wastes from the blood. The water also carries tiny food particles into the mouth and on through a short gullet to the stomach and intestines.

The clam possesses a foot that is not a foot at all but only a thick muscular mass which it uses when the two valves or parts of its shell covering are spread apart. This foot serves both as a means of anchorage and as an organ of locomotion. In a clumsy manner the clam plows through the soft mud, sometimes leaving a trail by which it may be followed in clear, shallow water.

The clam uses its gills as a nursery. Probably the most interesting life process of a clam or mussel is that of reproduction. The sexes are usually separate, which means that sperms are produced in one individual and ova or eggs in another. The sperms are carried from the male by the current of water passing through its body and on into the body of a near-by female. Some of the sperms lodge in the gills of the female, where the eggs are held, and here fertilization takes place. Next the gills serve as a brood pouch for the development of embryonic clams.

Very young clams and mussels lead peculiar and interesting lives. They clamp their tiny shells on the skin, gills, or fins of fish and live as parasites for a period of two months. During this time they develop a foot, and then drop off to begin an independent existence. In many cases young clams ride hundreds of miles attached to a fish. Here, again, we see how helpful are partnerships in nature, and we realize anew the interdependence that exists among life forms.

Snails

The slow-footed home owners. Some species of land snails, such as the garden slug, have no shell home and prefer to live in the open air. Most of them, however, build shells and add coil after coil as more room is needed. The real body of a snail

is soft and twisted to fit the coils of its shell. This does not mean, however, that it continually stays in its shell. On the contrary, it spends much time partly out of the shell, but draws itself in when danger appears.

"Slow as a snail" is rather slow, but the distance a snail can travel is remarkable. Like a clam, it has a foot, but it moves in a different manner. If an aquarium is near, it may be possible to watch a snail set its so-called "snail's pace." If so, we shall note wavelike contractions which start at the posterior end of the foot and move forward. It is by means of such contractions that the snail drags itself along. Whether the surface is smooth or rough, it maintains the same speed. This is because it secretes a slimy substance over which the foot glides. Thus it has often been said of the snail that it "lays its own track." This slimy material also protects the foot. Tests have been made to prove that a snail can even climb over the sharp edge of a razor without cutting itself.

SLOW AS A SNAIL

Underwood & Underwood

Snails like to roam, and though they travel slowly, they sometimes travel far. From the description given in the text, find the parts of the snail shown in the picture.

It is hard to believe that a snail has eyes, but it has. Protruding from the head of the land snail are two pairs of tentacles. Its eyes are borne at the ends of the larger and upper pair of these tentacles. The water snail has only two tentacles. Its eyes are located on the outer side of the tentacles not far from their base.

How the snail eats. Let us next look into the snail's mouth. Just below the tentacles are two horny plates or jaws that move up and down and cut the tissue of plants upon which the snail feeds. Attached to the bottom of the mouth is a long, narrow tonguelike membrane covered with rows of tiny teeth that point backward. The tongue can be forced in and out and serves as a rasp when drawn across a plant.

The Octopus

The eight-footed demon. The part of the octopus that corresponds to the foot of the clam and the snail is divided into eight tentacles or arms. In fact, the name *octopus* means "eight-footed." These tentacles are used as feet for creeping and as arms for grasping. A large octopus has been known to grasp and cling to a swimmer or a pearl diver,' holding him tightly in its grip until the unfortunate victim was drowned.

A FIERCE-LOOKING MONSTER OF THE DEEP

Underwood & Underwood

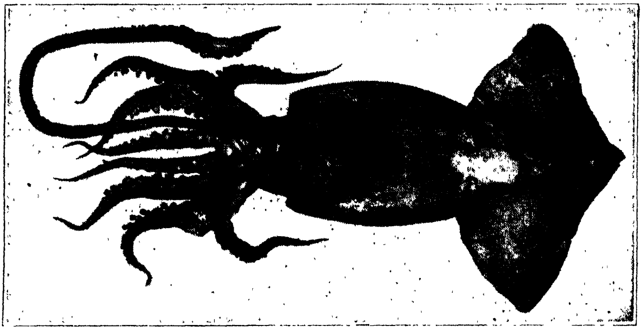
Suction disks on the eight arms (tentacles) of the octopus enable this many-footed animal to strangle its prey.

The oval-shaped body of an octopus is small in comparison with its long tentacles, sometimes being only about a foot long, whereas each tentacle may be as much as seven feet long. Its mouth is located near the center of its body, and in its head are two large well-developed eyes. From the foregoing description and the above illustration we can see that the octopus is extremely odd.

Many interesting stories have been told about the activities of the octopus. One of the most surprising features of its behavior is the manner in which it escapes. It does this by expelling a dark-colored fluid which serves as a smoke screen. So also do its relatives, the squid and the cuttlefish.

The flesh of the octopus is a rather important article of diet in certain Mediterranean ports and in Japan. The dark fluid from its body is used in the manufacture of drawing ink.

A NEAR RELATIVE OF THE OCTOPUS—THE SQUID



Courtesy American Museum of Natural History

In what ways does this peculiar animal resemble the octopus?

Value of the Mollusks to Man

The bivalves, such as the oysters, soft-shell clams, and scallops, are widely used as food. Certain large snails are also eaten, especially by the French, and squids by the Chinese and Italians. The shells of mussels are used in the manufacture of pearl buttons. Occasionally in oysters and mussels a valuable pearl is formed by a secretion from the *mantle*, the soft part that lines the valves. Finally, fresh-water mussels render a great service to man as scavengers, since they eat all sorts of animal and vegetable matter that would otherwise pollute water.

THE LARGEST GROUP OF LIVING THINGS THE ARTHROPODS

The phylum of *arthropods* includes more species than all other phyla of the animal kingdom combined. Distinctive characteristics of this great group of animals are *jointed appendages*, a *segmented body*, and an *exoskeleton*. The body consists of three main parts known as the *head*, *thorax*, and *abdomen*, although these parts are sometimes fused.

The most common arthropods belong to the following classes:

1. *Myriapods* (mĭr′ĭ-ȧ-pŏdz′)—*many-legged animals,* such as the millipede and centipede
2. *Insects*—*six-legged animals,* such as the bee, grasshopper, and beetles
3. *Crustaceans* (krŭs-tā′shănz)—*crusty-shelled animals,* such as the crab, crayfish, lobster, barnacle, shrimp, and sowbug
4. *Arachnids* (ȧ-răk′nĭdz)—*eight-legged animals,* such as the scorpion and spider

The myriapods, or many-legged animals, are so complicated and varied in structure that usually they are not considered in a high-school course. The insects, or six-legged animals, are discussed at length in Unit Five. Therefore at this point, we shall consider only the crustaceans and the arachnids.

Animals with Crusty Shells—The Crustaceans

A "cousin" of the lobster—the crayfish. Since the crayfish is similar to crabs, lobsters, and other crustaceans, we shall study this animal intensively for an understanding of the class as a whole. The crayfish lives naturally in fresh water, but it has many cousins, such as crabs, shrimps, and barnacles, that live in the sea. It feeds upon vegetation, decayed organic material, and the larvae of worms and insects. Its body is covered with a hard *chitinous* (kī′tĭn-ŭs) shell, or *exoskeleton,* impregnated with lime. This exoskeleton is divided into two regions: (1) a rigid anterior part called the *cephalothorax* (sĕf′ȧ-lō-thō′răks), which consists of the head and thorax more or less closely cemented together, and (2) a flexible abdomen consisting of six segments and a terminal extension.

Each segment of the crayfish, except the first in the female, bears a pair of jointed appendages. Extending from the head are two small segmented appendages, the *antennules* (ăn-tĕn′ūlz), and two long feelers, or *antennae* (ăn-tĕn′ē), which probably contain the sense of touch. Also extending from the head are two projections known as *eye stalks.* At the end of these stalks are compound eyes similar to those of insects (see

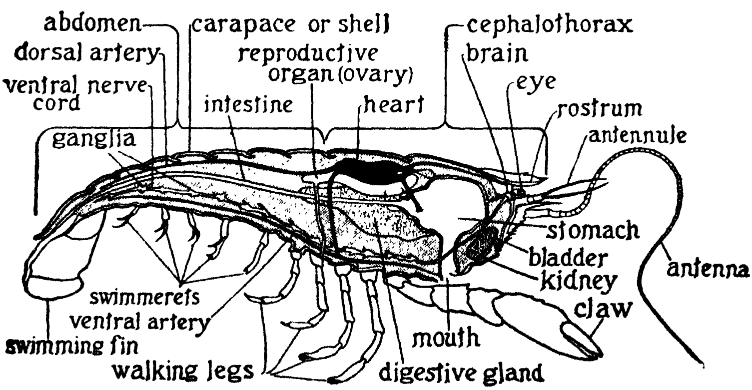
illustration on page 169). The surfaces of the eyes are divided into about twenty-five hundred rectangular faces or areas known as *facets*. Each facet is the outer surface of a single eye or *ommatidium* (ŏm′ȧ-tĭd′ĭ-ŭm). About the mouth of the crayfish are appendages known as *mandibles* and two pairs of *maxillae*.

Extending from the thorax are three pairs of jointed appendages known as *maxillipeds* (măk-sĭl′ĭ-pĕdz) which are toothed at the base and serve as jaws, and five pairs of walking legs. The first pair of legs, which are much larger than the others, are called *pinchers*, or *chelipeds* (kē′lĭ-pĕdz). These are probably so named because they end in great strong claws. The crayfish uses the chelipeds in defending itself, in moving about, and in capturing food.

Extending from each segment of the abdomen is a pair of appendages known as *swimmerets*. The crayfish uses these swimmerets for carrying its fertilized eggs and its young for about two weeks after they are hatched.

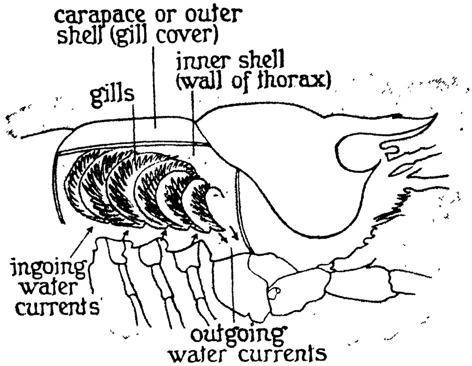
Looking under the shell. The following illustration shows what may be seen when the body of a crayfish is opened from head to tail so as to give a side view. We find that it has a complete digestive tract. This includes a mouth, a short tube

THE IMPORTANT PARTS OF A CRAYFISH



The crayfish, as shown in this illustration, has a complete set of organs. Note the location of some of the major organs, especially those of the digestive tract.

THE "BREATHERS" OF THE CRAYFISH



The thorax shell in this drawing of a crayfish has been removed to show the rows of small feathery gills. The crayfish uses these gills to extract oxygen from the air.

called an *esophagus* (ē-sŏf'ȧ-gŭs), which expands into a stomach, and a long, narrow intestine with an exterior opening. The heart lies in a sac in the upper and central part of the thorax. Blood vessels lead from the heart to all parts of the body. The crayfish breathes by means of two rows of gills which lie between the outer shell, or *carapace* (kăr'ȧ-pās), and the wall of the thorax.

The crayfish swims backward. Whereas nearly all of the swimming animals have developed a forward locomotion, the crayfish has the distinction of being different, for it always swims backward. It swims, however, only when frightened, propelling itself through the water with apparent ease by means of a flicking motion of its abdomen. Under ordinary conditions it walks, and is able to move forward, backward, or sidewise according to its fancy.

Animals Noted for Their Ugly Characteristics

The Arachnids

Certain species of the arthropods, like certain species of the mollusks, are among the most hideous of all living creatures. Furthermore, they add very little to the good of the world, as will be evident from the following study.

Scorpions

A story of a perilous scorpion. A beetle is meandering along on a hot summer day among the rocks and crevices of a tropical land. As it crawls about in search of food, it suddenly finds itself in the grasping claws of a deadly enemy, the scorpion. This enemy somewhat resembles an insect, but differs in that its head and thorax are united and it has eight legs instead of six. Extending from its head are appendages equipped with pincher-like claws that it uses for grasping and crushing. At the rear of its segmented body is a slender, sharp-pointed tail with which it stings and poisons its prey. The unfortunate beetle struggles violently to escape with its life. The scorpion, however, calmly curls its tail over the beetle and slowly prepares to apply its stinger. The critical moment arrives, and it inserts its sting. The beetle immediately weakens, shivers for a moment, then crumples in death. The scorpion always fights in this methodical manner and is indeed a master in carrying on poisonous work.

A DEADLY POISONER
THE SCORPION

Underwood & Underwood

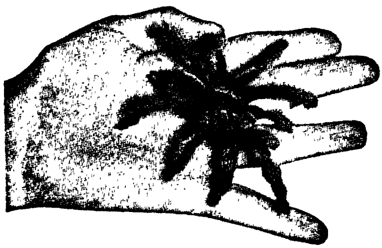
The hideous-looking scorpion paralyzes and kills its victim, such as a beetle, by means of a poisonous stinger. It also uses its stinger as a weapon of defense when it is hard pressed by an enemy.

Can a scorpion commit suicide? This question is difficult to answer definitely. Certain zoölogists claim that no animal can die of its own poison, nor can it poison an animal of its own kind. For example, a cobra, which is a poisonous snake, can poison neither itself nor another cobra. On the other hand, there seems to be a popular belief that a scorpion can take its own life. A movie newsreel, for example, recently pictured a scorpion being tormented by fire. According to this picture, rather than suffer burning, the scorpion thrust its sting into its back and died—a clear case of suicide.

Spinners, Weavers, and Builders of Spiderland

The crafty spider. Perhaps the most interesting and ingenious arthropod is the spider. This creature is predaceous and extremely skillful in capturing its prey. Often it traps its victims in a silken net; sometimes it leaps upon them from hiding-places; and again it captures them merely by speed.

A "NOT SO DANGEROUS" UGLY SPIDER



Courtesy *World Book Encyclopedia*

The size of the tarantula can be judged by comparison with the hand in this picture. The bite of the tarantula, while painful, has never been proved to be fatal.

The spider gets its ugly appearance largely from a pair of appendages attached to its head. These appendages, which are used for seizing and killing prey, consist of two segments. The outermost segment is claw-like and contains poison glands near its tip. A spider has two, four, six, or eight eyes, depending on its species. That it is well equipped with vision is apparent from the fact that some species have a set of eyes for use during the day and another set for hunting in the darkness of the night.

A spider spins by means of small appendages, known as *spinnerets,* which are located under the back part of the abdomen. These spinnerets contain small spinning tubes through which the silky substance is expelled.

The spider's knowledge of geometry. Although a spider school, with a requirement that all spiders must study geometry, does not exist, they display an amazing skill in measuring a web, in designing circles and triangles, and in weaving circumferences, diameters, and radii.

It is the female spider that does the work. Perhaps we can find a spider spinning her web and observe how she jumps or drops from one support to another, letting out and fastening a silken cable as she goes. Her thread is very fine, being only about one five-thousandth of an inch in diameter. She works steadily until she has inclosed an irregular space. Her next step is to weave threads toward the center which somewhat

resemble the spokes of a wheel. Then after making a few spiral turns to support the hub temporarily, she begins at the outside edge and puts in numerous circles toward the center. Finally she completes her task by removing the temporary supporting spirals. Some of the spirals that are left bear minute particles of a sticky substance that help to hold her victims.

How the spider catches its prey. The manner in which the spider catches her prey is as interesting as the manner in which she builds her web. She may either wait in the hub of the web for a victim or she may leave the web entirely. If she leaves, she builds telephonic cables, or, to be more exact, vibration cables, with which she keeps in touch with the web. When an unsuspecting fly or grasshopper enters, she feels the vibrations of the cables and immediately rushes for the prey. Then she binds the victim with more silk, poisons it, and proceeds to suck away its blood.

Trapdoor spiders. Among the most interesting architects of spider land are the trapdoor spiders. They excavate cylindrical holes in the ground, line them with silk, and seal the openings with silken trapdoors. These doors are sometimes equipped with hinges, and grooves are frequently made on the inside. When an enemy, such as a centipede, comes along, the spider holds its door shut by grasping the groove.

Spiders that use diving bells. Although all spiders are land animals and get their oxygen directly from the air, some of them have mastered the art of diving into water and of living beneath its surface. The water spider, for instance, dives into the water, builds a silken bag for a home, and attaches it to an underwater plant. This bag is aërated by bubbles of air which cling to the spider's body as it enters the water. Every time it makes a trip to its diving-bell home, it carries a few bubbles of air.

Air-minded spiders. Spiders became air-minded a long time before man invented his first balloon. The aeronautic or ballooning spiders spin silken threads which have such buoyancy that they are lifted into the air. When a landing is desired, they spin a landing rope and gradually descend.

THE INGENIOUS DEVICES OF SPIDERS

Courtesy *New Wonder World*

Near the top two ballooning spiders are floating by means of bouyant threads. At the lower left a trapdoor spider is entering its home. At the lower right several diving-bell spiders are carrying air to their homes beneath the surface of the water.

THE HIGHEST GROUP OF LIVING THINGS
THE CHORDATES

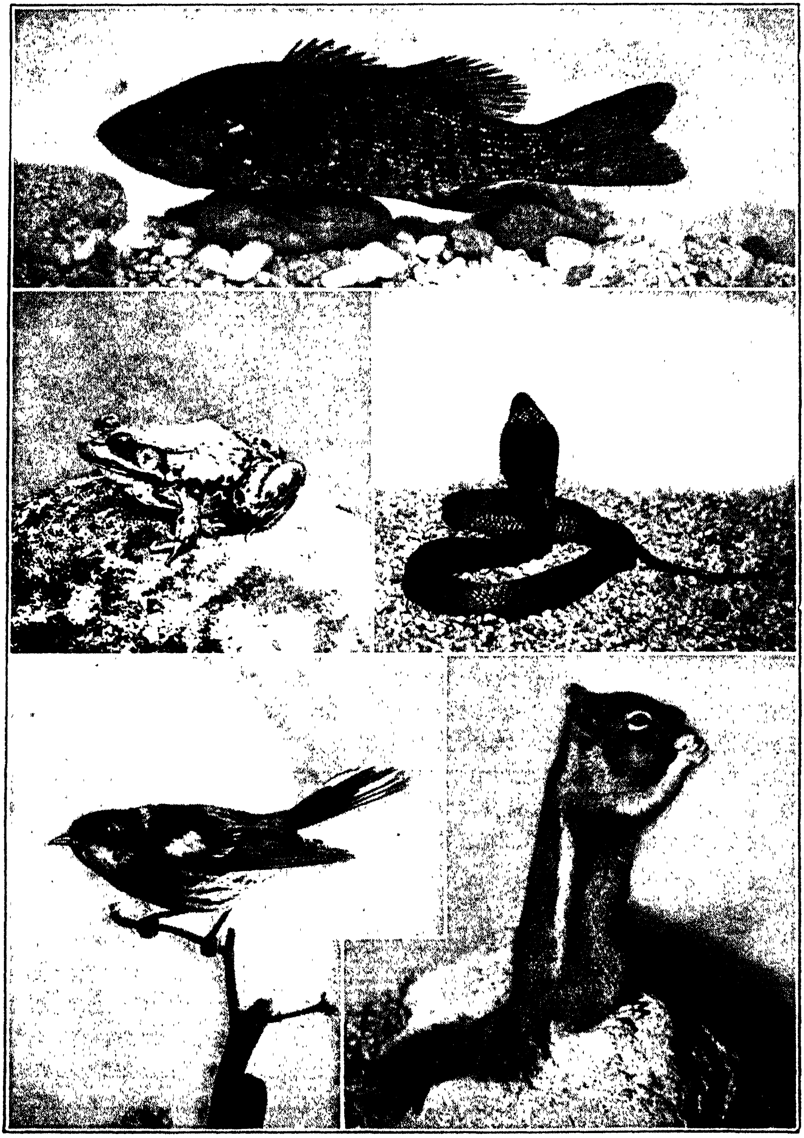
Only the members of the subphylum vertebrates (see page 302) will be considered here. The *vertebrates* are the dominant animals of the earth. They can do more things and do them better than the members of any other phylum in the entire animal kingdom. Through a highly developed nervous system they react to many more and to much more complicated situations than do the animals of the other phyla. The vertebrates include *fishes, amphibians, reptiles, birds,* and *mammals.* They are bilaterally symmetrical, which means that the right and left sides of the body are similar. The skeleton is within the body and is held together by strong bands of tissue. The distinctive feature of all vertebrates is the *backbone,* or *vertebral column.* The animals discussed thus far are called *invertebrates* because they have no inner skeleton or vertebral column.

The skeleton of vertebrates consists of two parts: (1) the *axial skeleton,* including the *skull* and the *backbone,* and (2) the *appendicular skeleton,* including the *pectoral girdle* to which the anterior or *pectoral appendages* are attached, and the *pelvic girdle* to which the posterior or *pelvic appendages* are attached. In man the pectoral appendages are known as *arms* and the pelvic appendages as *legs.* In fish the appendages are called *fins,* and in birds the pectoral appendages are *wings.* Nevertheless, vertebrates have many points in common:

1. An inner skeleton
2. A backbone composed of vertebrae
3. A well-developed nervous system with large brain
4. Four body cavities: cranial, thoracic, abdominal, pelvic
5. Never more than two pairs of limbs
6. A chambered heart permitting double circulation
7. Eyes, ears, and nostrils always on the head
8. Jaws which move up and down
9. Usually teeth

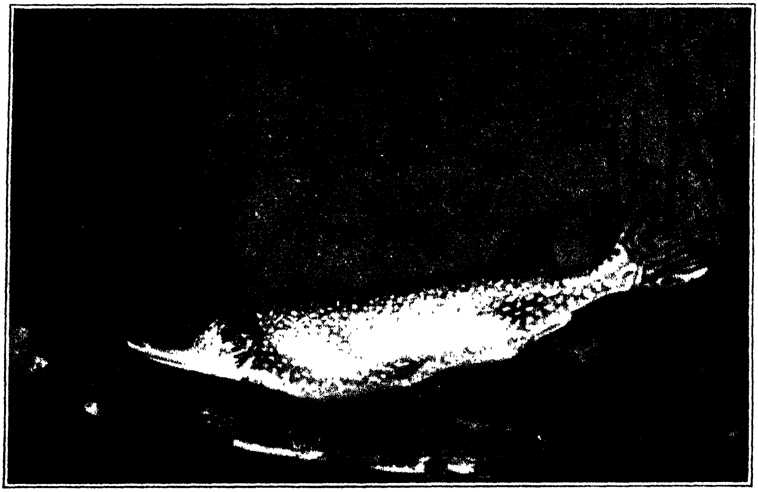
By checking the parts of the human body with the above list, we can readily see that man is a vertebrate.

A GROUP OF VERTEBRATES



The subphylum vertebrates includes the most highly developed animals on the face of the earth: fishes, amphibians, reptiles, birds, and mammals. Which of the above illustrations represents each of these groups? Which group is the most advanced?

A FISH THAT HAS JUST SATISFIED ITSELF WITH A HEAVY FISH DINNER



Courtesy *Washington Post*

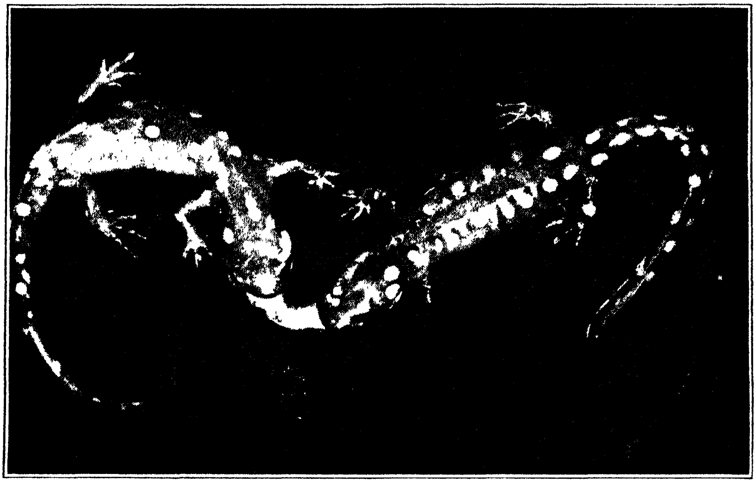
This pickerel has just eaten a two-pound fish, an unusually large meal. Most fish are not so gluttonous, being content to consume small fish about the size of minnows.

WATER DWELLERS—THE FISHES

All *fishes* are vertebrates, but many animals called fish are not even closely related to them. The jellyfish, starfish crayfish, and others that we have studied, for example, are not true fishes, but belong to certain classes of invertebrates. They are called fish merely because they live in water and somewhat resemble true fishes.

There are four orders of fishes, the *bony*, *armored*, *cartilaginous*, and *lung* fishes. Of these orders, the bony fishes include about 95 per cent of all the species. They are represented by such well-known members as trout, bass, pike, perch, shad, menhaden, cod, mackerel, sunfish, and goldfish. Some of these members are inhabitants of the sea, others of fresh-water streams and lakes near our homes. The fact that fishes are cold-blooded and live in the water makes them more or less curious and unusually interesting to study. We shall forego further consideration of fishes at this particular point, however, since they come up for an extensive discussion in Unit Eight.

A PAIR OF AMPHIBIANS FIGHTING OVER AN EARTHWORM



Hugh Spencer

Both of these salamanders are intent on getting the same worm for dinner. There is no way of telling which will win in the end. They may come out even.

LAND AND WATER DWELLERS—THE AMPHIBIANS

The *amphibians* are like fishes and reptiles in that they have backbones and are cold-blooded. They differ from fishes and reptiles, however, in that they have a smooth, slimy covering which helps them in breathing or taking in oxygen. Frogs and toads are tailless after they have developed beyond the tadpole stage. Salamanders, however, have tails, and are often mistaken for lizards even though their skin is soft and scaleless. Thus it is clear that as a class the amphibians are hard to describe. About the only common characters are the following: (1) a slimy skin without scales and (2) short fore and hind legs that end in four or five fingers or toes.

As a group the amphibians are timid animals that do not scratch, bite, or sting. About their only means of protection is flight or concealment. They comprise three orders, one of which lives in the tropics and the other two in the temperate belts. Of these, one includes *tailed* amphibians, such as

FROM ONE CREATURE TO ANOTHER

Courtesy New York Zoölogical Society

This picture shows various stages in the development of the frog. At the extreme left is a young tadpole without feet, in the center are two tadpoles with two feet, and at the right are two more with four feet. At the top is a fully developed frog.

mud puppies and salamanders. The other includes *tailless* amphibians, such as frogs and toads.

From tadpole to frog. We shall now consider one of the most interesting romances of biology—the life history of the leopard frog. The female begins to lay her eggs two or three weeks after the thawing of winter ice. As a place for depositing her eggs she usually picks a location in shallow water near the edge of a pond or small lake. According to her size she may lay from two thousand to ten thousand eggs at a time. The eggs are inclosed in a mass of jelly-like substance, which is usually attached to some plant. A male is usually at hand to fertilize the eggs, and a week or ten days later, if the weather is warm, they hatch into tiny dark-brown *tadpoles*.

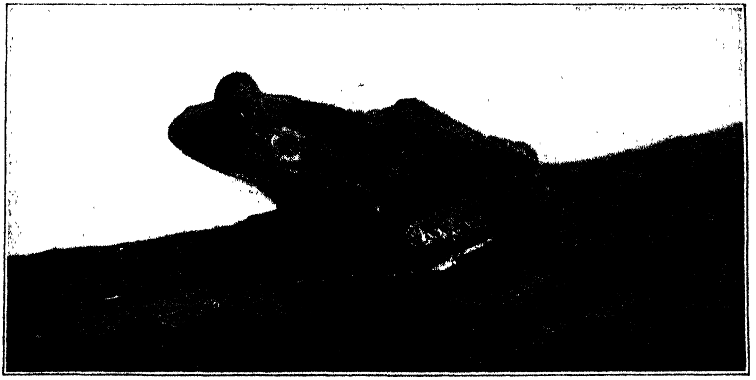
Each tadpole is provided with external gills for breathing, a tail for swimming, and a pair of horny jaws for chewing bits of vegetation. The external gills disappear and new ones form somewhat resembling those of a fish. During the next eight or ten weeks the tadpole becomes full grown, with a tail three or four inches in length. When its development seems to be complete for a water existence, it begins to make

ready for a life on land as well. Lungs form and it begins to swim to the surface to take some of its oxygen directly from the air. As this continues, the lungs function more and more and the gills disappear.

The tale of the tadpole's tail. While lungs are taking the place of gills, hind legs appear, then front legs. At the same time the tail is absorbed and completely disappears. The last statement answers the oft-asked question, "What becomes of a tadpole's tail?"

The little frog child has all of the characteristics of a grown-up—strong legs, with five long, webbed toes; shorter arms, with four fingers on each hand; a spotted, moist skin; a wide mouth and a long, forked tongue which shoots out with great speed and accuracy to catch its small prey. For a time in the spring or early summer it stays close to the water, jumping in at the first sign of danger. Later it may wander far from home. With the approach of winter it buries itself in soft mud, usually at the bottom of a pond. Here it remains dormant, with its organs inactive, until the following spring. Thus it continues to grow for four or five years. Then if it is fortunate enough to survive certain unfavorable conditions and to outwit its enemies, it may live for twenty or thirty years.

A FAMILIAR FRIEND—THE BULLFROG



Courtesy New York Zoölogical Society

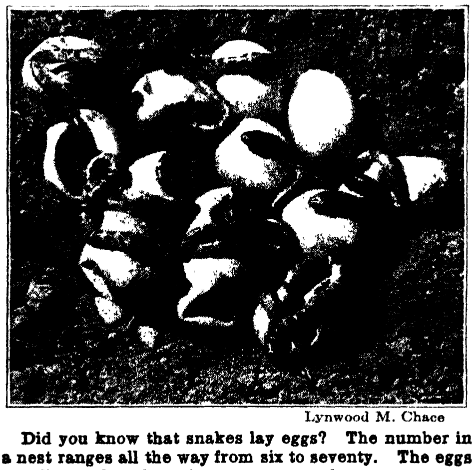
The bullfrog, a common inhabitant of ponds in most parts of the country, has been so named because of its heavy build and its tendency to give forth bellowing sounds.

The frog's usefulness. The frog is a friend to man, catching a great many insects. In addition to insects, it catches worms, snails, tadpoles, and other frogs. Strangely, it consumes only living things, especially those in motion. In fact, it entirely ignores dead insects, which it readily consumes when they are alive. Likewise, it ignores motionless worms, which it seizes when they are in motion. When it takes something into its mouth that it does not like, it ejects it much as we eject food that we dislike. The frog not only helps us by consuming a great many pests, but it also serves as food itself. Frog legs are served in hotels and restaurants in many parts of the country. The frog also serves as an excellent specimen for laboratory work.

WHO'S WHO AMONG THE REPTILES

Reptiles are cold-blooded, scaly creatures that differ greatly from their cousins, the amphibians. Although they are true land animals and never breathe by means of gills, many of them live near water and spend much of their time in it. All water-loving reptiles, however, must come to the surface to breathe. Reptiles differ from the amphibians in that they have no distinct metamorphosis and their eggs are fertilized internally. Certain reptiles give birth to their young, while others lay shell-covered eggs from which the young are hatched. The popular opinion that reptiles are slimy and that all of them are dangerous is wrong. In fact, most of the reptiles in the United States are harmless, and some are even useful. Among

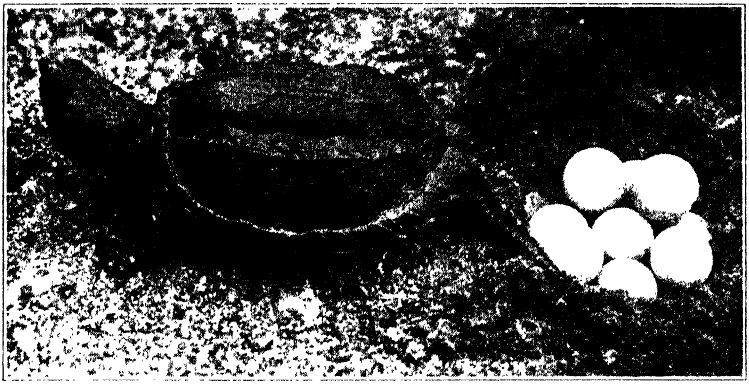
SNAKES EMERGING FROM EGGS



Lynwood M. Chace

Did you know that snakes lay eggs? The number in a nest ranges all the way from six to seventy. The eggs usually hatch in from five to seven weeks.

SNAPPING TURTLE



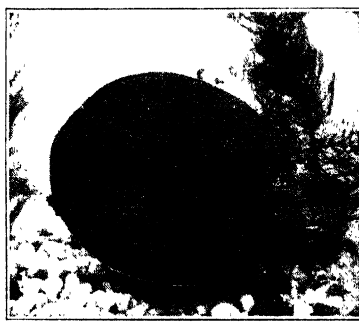
Lynwood M. Chace

After carefully scanning the near horizon to make certain no enemy is looking, the cautious turtle covers her round white eggs and crawls slowly back to the swamp.

the representatives of the various orders the following are the most important: *turtles*, *lizards*, *crocodiles*, and *snakes*.

The slow but sure reptiles—turtles. Turtles are protected from enemies by shells or armor over their bodies. Only the head, legs, and tail are exposed. Because of the armor they are sluggish and awkward in their locomotion. Among the more interesting species are the box turtle, which can draw its head and tail completely within its shell; the snapping turtle, known for the manner in which it "snaps" at its prey; the painted turtle; and the giant green turtle of the sea. Turtles differ greatly in their choice of food. Those which live on land subsist on a wide variety of insects and worms. They also eat a great deal of vegetation. Those which live in the sea feed on fish, crayfish, frogs, and water-

A TURTLE WITH A SOFT SHELL



Courtesy New York Zoölogical Society

There are four species of soft-shelled turtles in the United States. The larger specimens dart their heads about very rapidly, and often inflict ugly wounds.

fowl. Land turtles are commonly spoken of as *tortoises,* and water species as *turtles* and *terrapins.*

Fantastic reptiles — the lizards. Lizards are interesting creatures wholly unlike the turtles. They are covered with scales

A LIZARD WITH A POISONOUS BITE

Courtesy New York Zoölogical Society

Only two lizards are venomous, the Gila monster, shown above, and a similar species found in certain parts of Mexico. The Gila monster bites when it is angry, giving off a deadly poison. Note that its markings closely resemble Indian beadwork.

instead of protective shells, are fleet of foot, have movable eyes, and, usually, long tails. Interesting indeed is the fact that their tails are regenerated when broken off. Lizards may be called fantastic reptiles because of their many odd and varied types. The chameleon (kȧ-mē′lê-ŭn) with its changing colors, the frilled lizard, the flying dragon, and the poisonous Gila (hē′lȧ) monster of New Mexico and Arizona illustrate the varied fantastic types. It is from some of the weird lizards that the legends of giant dragons have originated.

The largest reptiles — crocodiles and alligators. For the most part crocodiles and alligators are lazy reptiles that spend much of their time floating in the water or basking on the shores. They differ from lizards in their general appearance because they have long snouts and heavy scales. Crocodiles are usually larger and more dangerous than alligators, sometimes attaining a length of twenty feet.

A LARGE REPTILE—THE ALLIGATOR

Courtesy American Museum of Natural History

The alligator is found from North Carolina to Florida and westward to the Rio Grande in Texas. It may be distinguished from its cousin the crocodile by its wider nose and head. Like the crocodile, however, it appears very clumsy and lazy.

The king snake. If we were to make a list of the castes in the society of snake folks, it would probably be proper to list the king snake as chief of our native reptiles. It is not a large snake, being only from one to five feet long, but it is very powerful for its size. Yellow or white chain-like markings give its black body a commanding appearance. As a conqueror of poisonous snakes, it has gained a wide reputation. It rejoices in a fight with poisonous rattlers and copperheads and, strange to say, is nearly always victorious in its conflicts.

THE CHIEF AMONG OUR NATIVE SNAKES

Courtesy New York Zoölogical Society

The king snake should be protected, not only because it is a destroyer of poisonous snakes, but also because it preys upon rats, mice, and other rodents.

The story of an attack upon a rattler. Suppose that a large rattlesnake is winding its way through a dense woods and comes upon a king snake. The king snake gives forth a hissing sound, showing that it is eager to fight. The rattlesnake,

however, merely rattles as if to say, "I'll be on my way." The king snake, on the other hand, is greatly insulted and says, "Who are you that you can shake a rattle in my face?" With this remark it suddenly strikes at the rattlesnake, and the fight is on. The rattlesnake, thoroughly aroused, now begins to fight back. Quickly it darts at the king snake, sinks its poisonous fangs, and feels assured of success. The king snake, though, is immune to the deadly fluid and is only irritated by the bites. At last, its moment has come. It coils its body about the rattler, tightens its grip, and the rattler is no more.

Dangerous snakes. In respect to habits, dangerous snakes may be divided into two types: those that kill by strangling and those that kill by sinking poisonous fangs. Of the poisonous land snakes, about one hundred fifty species belong to the family Colubridae (kŏ-lū'brĭ-dē). The members of this family have slender, cylindrical bodies, such as the cobra, krait (krīt), and coral snake. About one hundred other species of poisonous land snakes belong to the family Viperidae (vī-pĕr'-ĭ-dē). These include thicker-bodied members, such as the rattler, the copperhead, and the water moccasin. About fifty species of poisonous sea snakes inhabit the waters along the coasts of Africa and southern Asia.

Chief among the snakes that strangle their prey are the boa constrictor, the anaconda, and the python. All of these snakes inhabit the tropical jungles. The boa constrictor sometimes attains a length of about twelve feet. The anaconda, however, grows to be as long as thirty feet, as does also its close rival, the handsome yellowish-brown python.

The dreaded cobra. The cobra is considered the most deadly of all snakes, causing the death of twenty thousand people annually in the country of India. It is often called the hooded terror because, when disturbed, it holds its head erect and puffs out its neck. The peculiar hood is formed by the ribs of the neck, which the snake raises, stretching out loose folds of skin. These features, plus a darting tongue and glaring eyes, give it a fearful death-spelling appearance.

The cobra does not attack until it has been disturbed, and then it becomes ferocious. The high death rate in India is due partly to the fact that the people there worship the cobra as a sacred animal and consequently refuse to kill it. Then, too, it is often disturbed when it enters their poorly constructed houses in search of mice and rats.

Poisonous snakes of the United States and Canada. Since in North America only a few deaths annually occur from snake bites, we are likely to ignore the danger of snakes. If we spend much time out of doors in regions where rattlers, copperheads, water moccasins, and coral snakes live, it is essential that we learn to identify them, for they are extremely venomous. Rural territories are, of course, much more infested with snakes than city lots. During camping or hiking trips we should be careful when stepping near or into tall grass and bushes, when climbing among rocks and crevices, or when wading along streams, lest we disturb a poisonous reptile. Such a snake usually will not pick a fight, but it will strike quickly when aroused.

A POISONOUS RATTLER

There are about a dozen species of rattlesnakes. Note the rattles at the end of the tail.

A rattler can be identified by the rattles on its tail. The copperhead is just what its name implies—a snake with a copper-colored head. Its body, especially near the middle, is covered with alternating light and dark patches. The water moccasin has a thick brownish body. When disturbed it shows white mouth parts, and consequently in certain localities is known as a "cotton-mouth." The coral snake is found chiefly in the southern and southwestern parts of the country. It

has a small cylindrical body and makes an imposing appearance with its alternating bands of red, yellow, and black.

The treatment for snake bites. When a person is bitten by a poisonous snake, first aid should be administered immediately. A rope, a string, or a tourniquet should be tied above the bite and twisted with a stick, so as to keep the poison from getting into the general circulation. The wound should be cut sufficiently to cause it to bleed freely, thus washing out the poison. There is some doubt as to whether the wound should be sucked. If it is, certainly the person who does the sucking should spit out the poison-laden blood as quickly as possible. After the cut has bled copiously, it should be sterilized with silver nitrate or potassium permanganate. The binding which was tied above the bite must be removed in a half-hour or gangrene may develop. Mild heart stimulants will help offset the shock and loss of blood. A doctor should be secured as soon as possible after first aid has been administered.

Snakes widely scattered. Snakes seem to make their homes in nearly all parts of the world. They live in tropical jungles, along ponds, in swamps, on mountain tops, on the deserts, in the sea, in burrows in the ground, among rocky crevices—in fact, wherever food and shelter may be found. About the only places in which they are not found are regions of extreme cold and a few islands. As has already been pointed out, although snakes are land animals and air breathers, a great many of them prefer to be in or near water. The great lung capacity of sea snakes enables them to take a deep breath and then to stay submerged for some time.

Their graceful gliding motion. In their method of locomotion snakes show great skill and speed and seem to flow gracefully from one place to another. Peculiarly, however, they walk with their ribs. They alternately expand and contract the muscles that connect their ribs with the scales, or *scutes* (skūtz), on the outside of their bodies. In other words, they merely pull themselves along by catching their scales on rough edges. This is proved by the fact that they cannot travel on highly polished surfaces, such as marble or glass.

Many snakes friends of man. We are likely to be prejudiced against snakes because of their repulsive appearance or because some of them happen to be poisonous, but actually many of them are our friends. They eat such pests as insects, rats, mice, and even certain species of venomous snakes. Some snakes are also beautiful and in captivity become docile pets.

Air-minded Animals—The Birds

The vertebrates usually studied next are the *birds*. Birds are distinguished in several ways from the animals that we

WILD DUCKS IN FLIGHT

Century Photos

Notice how the ducks follow a leader in artistic formation.

have met earlier in the unit. Among their distinctive characters are the following: (1) their pectoral appendages are modified into *wings;* (2) their bodies are covered with *feathers;* and (3) they are *warm-blooded.* Cold-blooded animals, of course, have no heating systems of their own. When the air or water surrounding them grows warmer, their bodies grow warmer also; when the surrounding air or water grows colder, their bodies, too, grow colder. If the surroundings become sufficiently cold, such animals grow more and more sluggish and finally are unable to move. In colder parts of the world,

cold-blooded land animals must *hibernate* in winter. That is, they sleep through the period when they would be too stiff with cold to move. Birds and mammals alone are able to keep their bodies at a constant temperature by means of their own internal heating plants, and are therefore able to remain active in winter.

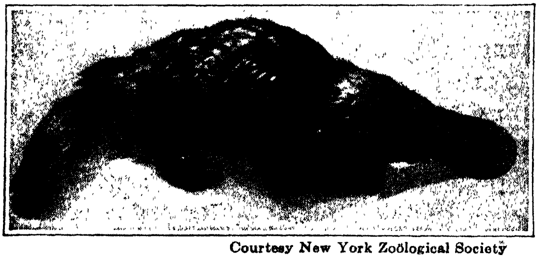
Since birds are discussed in detail in Unit Eight, we shall not pause to consider them here, but will go on at once to the other class of warm-blooded vertebrates, the mammals.

The Family Animals—The Mammals

The *mammals*, as we have already learned, are more highly developed than the animals of any other class. They include not only our own kind but most of the animals with which we are associated in our daily living, such as dogs, cats, and horses around the home or on the street, and cattle, sheep, and swine on the farm. That the class includes a wide variety of interesting species will be apparent from the following stories and descriptions.

The egg-laying mammals. Two of the most curious creatures belonging to the mammalian class are the duckbill, or platypus (plăt′ĭ-pŭs), and the echidna (ḗ-kĭd′nȧ), which are found in Australia. These animals are unique because they lay eggs, whereas all other mammals bear their young alive. When the eggs are hatched, the female nourishes the young with milk secreted from the mammary glands. The duckbill lives along streams and digs a long burrow as its home. It sleeps during the day, but at night it probes around the bottom of streams in search of worms, insects, and other small forms of life. The echidna lives largely upon ants.

THE MOST PECULIAR OF ANIMALS



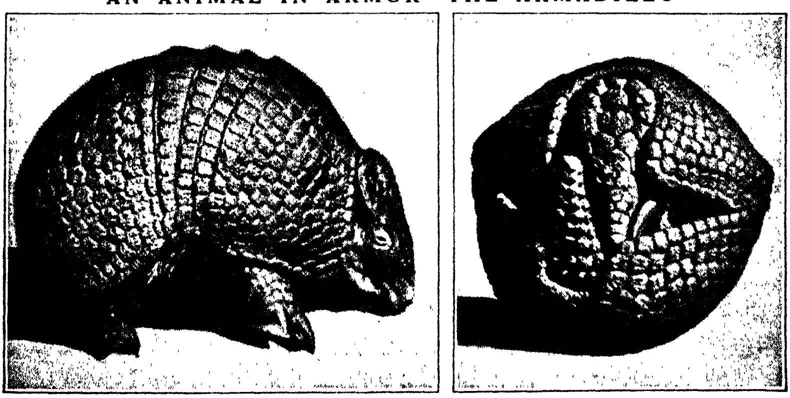
Courtesy New York Zoölogical Society

Who has not heard of the mammal which lays eggs like a snake, has a bill like a duck, a tail like a beaver, and takes to water like a fish? This creature is the duckbill (platypus).

The toothless mammals. The animals belonging to the order of so-called toothless mammals either have a few imperfect molars or no teeth at all. In general, the animals are of little importance from an economic standpoint. Two of the most interesting species are the sloth and the armadillo. The sloth is found along the Amazon River in South America. It probably lives more consistently in the trees than any other quadruped. In fact, it may spend its whole life in a single tree. It hangs from a limb by means of its hooklike claws, with its back downward. In other words, it hangs upside down. As we may expect, it is slow and inoffensive. It moves about very little, mostly at night in search of food, such as leaves, young shoots, and fruit. There are two kinds of sloths, the two-toed and the three-toed. Both kinds are covered with coarse grayish hair. Algae, however, grow in the hair and give it a greenish color similar to that of the foliage.

The armadillo is found in both North and South America. This strange creature wears a coat of mail made of little bony plates. It differs greatly in size, its body varying in length from five or six inches to four or five feet. Its color is usually brownish black, with yellow and yellowish-white markings. The most interesting fact about the armadillo is its ability to

AN ANIMAL IN ARMOR—THE ARMADILLO



The armadillo is well protected by its bony exoskeleton and its ability to roll itself up into a ball. The picture at the left shows how it looks as it moves slowly from one place to another. The picture at the right shows how it looks when it is rolled up into a ball.

roll itself up into a ball. This ability serves as a good protection from enemies. The armadillo moves about largely at night. Its food consists of fruit, insects, roots, and worms. The natives sometimes use its flesh for food. They also use its bony exoskeleton for making fancy baskets.

The pouched mammals. The kangaroo of Australia and the opossum of our own country are the best-known members of the order of pouched mammals. They differ from other mammals in that the female possesses a *pouch* on the ventral side of the abdomen in which she places her young immediately after birth. Kangaroos vary in size from the rat kangaroo, which is only about fourteen inches long, up to the great gray kangaroo, which stands more than four feet in height and often weighs as much as two hundred pounds. The kangaroo does not look for trouble, but will put up a good fight when cornered. It does this by shooting out its strong hind legs while sitting back on its long massive tail. If it chooses to run rather than fight, it can do so with amazing rapidity, covering about fifteen to twenty feet with each leap.

AN AMERICAN MARSUPIAL

Courtesy *Nature Magazine*

The opossum is the only marsupial of any kind found in North America. Strangely, there are no opossums in Australia, where nearly all the other marsupials live.

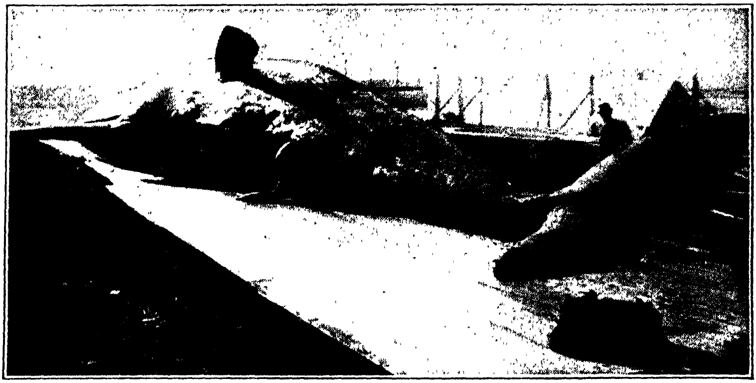
The opossum is most common in the southern part of the United States, and is hunted not only for its fur but also for food. The expression "playing possum" gets its origin from the fact that when captured the creature pretends to be dead. Some believe, however, that it is merely paralyzed from fright.

The fishlike mammals. Whales, dolphins, and porpoises are often referred to as fish because they live in water and somewhat resemble fish in their appearance. They are true

mammals, however, the young being born alive and nourished by milk just as are the young of mammals on land.

Whales are the largest living animals and are noted for their spouting. They breathe through nostrils that open into a

WHAT A "WHALE" OF AN ANIMAL



Century Photos

The blue whale, which is shown above, is the largest of the mammals. It may attain a length of 90 feet and weigh as much as 150 tons. Such a great mass of living matter is equivalent to the weight of thirty to fifty elephants or approximately two hundred cattle.

single hole in the top of the head. About once an hour they must come up for air. While on their way to the surface they expel the old air from their lungs, sending up spouts of water that somewhat resemble small geysers. After spouting many times, they take in fresh air and return below the surface.

Whales probably would not be in existence today except for the fact that they took to the sea many ages ago. Each year thousands of them are killed for their oil. Whaling has for years been a profitable business in some parts of the world, regular ships known as whaling vessels being used for the purpose. When a whale is killed, its body is drawn to the deck and sawed into chunks. The chunks are sent down chutes into a rendering plant in the lower part of the ship to be turned into oil. A full cargo of whale oil may be worth as much as two million dollars.

The gnawing mammals, or rodents. Some mammals have long, chisel-like teeth, and are usually considered destructive.

All of these animals are little creatures, such as rats, mice, rabbits, and beavers. Although the rodents do sometimes annoy us, and even damage our property, some of them, as rabbits, beavers, and squirrels, reward us by furnishing food and clothing.

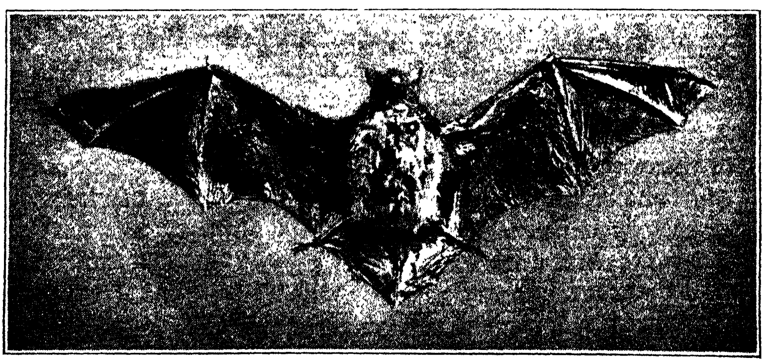
THE MOLE A MINER

This mammal is well adapted for digging through the dirt underground. Here it is shown in its burrow, where it lives and searches for food.

The insect-eating mammals. The best known insect-eating mammals are the shrew and the mole. The shrew is the smallest mammal known, measuring only about two inches in length. The mole may seem to be a nuisance as it bores its way across lawns, but it is really useful, consuming grubs and the larvae of a great many insects. It has crude eyes which enable it to distinguish light from darkness but which give it little help in catching prey.

The winged mammal. Bats are the only members of the order of winged mammals. Perhaps we have seen one of these

THE ONLY FLYING MAMMAL



Century Photos

The bat is often considered rather weird because it flies about only at night. Aside from its wings it looks somewhat like a large mouse. Although it looks very strange, it is really a friend of man because it consumes a great many insects.

weird creatures darting about on a summer night in search of prey. Upon close inspection it somewhat resembles a mouse with wings. Its wings, however, are not real wings but broad pieces of leathery membrane stretched backward from the forearms to the feet and tail. In general, the bat is harmless and may be considered an ally of man because of the insects it destroys. There is one exception, the vampire bat of South America, which sucks the blood of animals and even bites human beings while they are asleep.

The flesh-eating mammals. One of the largest groups of mammals are the flesh-eating mammals, or *carnivores* (kär′nĭ-vôrz) (Carnivora), which have large projecting canine teeth well adapted to cutting and tearing tissues. These flesh-eating mammals include the bear, lion, tiger, leopard, wolf, fox, raccoon, weasel, seal, walrus, and many others, including two close friends of man, the dog and the cat. Each mammal is protected by hair or fur, and each has toes provided with claws. Few of the flesh-eating mammals furnish

A LION AND ITS KILL

Wide World Photos

The camerman took a great risk when he obtained this picture.

us with food, but they add much to our comfort by giving us valuable furs. Among the chief animals caught for their furs are the fox, seal, wolf, raccoon, and leopard.

Most flesh-eating mammals have a very acute sense of smell which enables them to follow or track their prey. In general, they are wandering hunters. They cannot remain in any one place as do plant-eating animals, for they must follow their prey. Some of them, however, such as the fox and bear, live in holes in the ground known as dens. Some, such as bears and raccoons, eat both plant and animal foods.

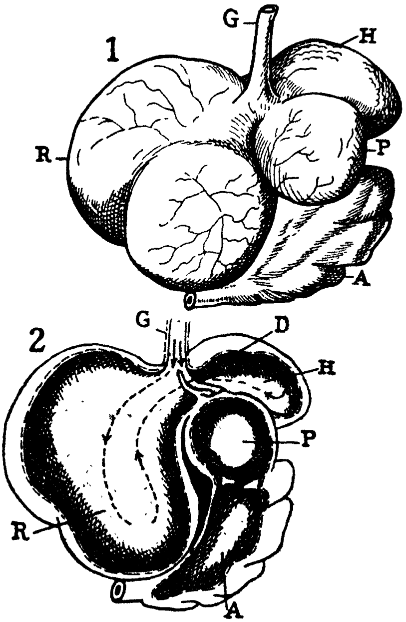
From our own knowledge of the foregoing animals we can readily understand why they are particularly well adapted to the capture of prey. Indeed, they are so well adapted to pursuit that many hoofed mammals are unable to get out of their way. Many hoofed mammals have been domesticated, but of the flesh-eating mammals only two, the dog and the cat, are willing to live in contentment with man.

The hoofed mammals. A well-known order of mammals is composed of animals whose extremities end in a single hoof of from two to five toes. These animals all have strong molar teeth with broad surfaces that enable them easily to grind the vegetation upon which they live. Most of them have a sidewise motion of the jaw which greatly aids in the grinding process. The hoofed mammals include our most important domestic animals. We not only depend on them for part of our food, shelter, and clothing, but we also use them as beasts of burden. For purposes of study we may divide the hoofed mammals into three groups: those with an even number of hoofed toes, as the pig, hippopotamus, camel, giraffe, deer, moose, domestic cattle, and bison; those with an uneven number of hoofed toes, as the horse, zebra, tapir, and rhinoceros; those with a long proboscis or trunk on the head, as the elephant.

Certain species of the even-toed mammals are known as *ruminants* because they chew the cud. The cow grazing in the pasture, for instance, nibbles off grass, compresses it into little balls, and swallows it without chewing. These balls of grass

pass into one of the four compartments of the stomach called the *rumen* or *paunch,* which serves as a storehouse for food hurriedly eaten. Then, after the cow finishes eating, the food from the rumen is brought back in small quantities (*cuds*) to the mouth, where it is completely masticated. After being swallowed the second time the food goes to the other compartments of the stomach for continued digestion. This method of feeding permits defenseless animals to gather a large quantity of food in a short time, after which they can go to some safe place to chew in peace and contentment.

STOMACH OF A RUMINANT



Stomach of an ox: (1) outside view and (2) cut open. The food or grass which is cut off by the incisors in the lower jaw is rolled into balls and passes through the gullet (G) into the first compartment, the rumen (R); thence through a connecting passage into the second compartment, the honeycomb or recticulum (H); thence back into the mouth, where it is thoroughly masticated; passing once more through the gullet and a duct (D), it enters the third compartment (P), finally going into the fourth (A).

The erect mammals. At last we have come to the order of erect mammals, which is the highest in all the animal kingdom. The name *Primates,* which means "chiefs," was given to the animals of this order in 1758 by the Swedish scientist Linnaeus. They include the lemur, baboon, monkey, orang-outang, gorilla, chimpanzee, gibbon, and man. A close study of the Primates reveals the fact that their superiority comes from a more complex development of the brain.

Since man, the highest of all, assumes such an important rôle elsewhere in this book, no further discussion of erect mammals will be given at this point.

SUGGESTED ACTIVITIES

I. Self-Organization Summary

A. In this unit you have made a wide study of plant and animal life. It will be helpful now to prepare a chart for the purpose of organizing your thinking. The chart should contain four columns. In the first column list the names of the plant and animal phyla; in the second column list the characteristics of each phylum; in the third column list the more important classes comprising each phylum; and in the fourth column list a few of the most common species composing each class.

B. Make a list of what you consider the most important facts to be remembered about each phylum, such as characteristics, habitats, methods of reproduction, and economic value.

II. Laboratory Study

The laboratory work for this unit may well consist of a variety of activities. The range of subject matter is so great that no one phase of activity will suffice. The general nature of studies that may be made are illustrated by the following:

A. Microscopic examination of algae, fungi, and lichens
B. Dissection and drawing of mosses and ferns to show the reproductive organs
C. Dissection and drawing of typical flowering plants to show the essential parts
D. Dissection and drawing of sponges, sea anemones, earthworms, clams, starfish, fish, frogs, and rats to show important internal structures
E. Examination of preserved materials, models, and mounted specimens for an understanding of unfamiliar forms of life
F. Preparation and mounting of specimens to form collections of life in the local community

III. Display Posters

Make large displays of pictures of plants and animals by grouping them on large cards. Many desirable pictures for the purpose may be secured from newspapers and magazines. The pictures may be grouped according to phylum, class, or order, or according to some special characteristic or habit unrelated to their biological classification.

IV. Field Trips

If your school is located near a zoo, a botanical garden, or a natural history museum, you should visit each of them for the purpose of studying unfamiliar forms of life. The plant and animal life of your own community is even more important and should not be overlooked in your study. Now is an excellent time to learn to recognize the more important plants and to collect some of them for intensive examination. The behavior and characteristics of wild and domestic animals should also be observed as far as possible.

V. Special Reports

No doubt as you have read the topics in this unit questions have arisen which could not be fully discussed at the time. Then, too, there may be various other topics related to those in the unit about which you would like additional information. Many of these topics will make excellent subjects upon which to report to the class. The following list of subjects is submitted as representative of those you may wish to develop:

A. An acquaintance with turtles
B. A visit to crocodile land
C. Precious corals
D. Lizards and their ways
E. Interesting facts about monkeys, baboons, and apes
F. Air-minded mammals
G. The sponge industry
H. Variation in mollusk shells

REFERENCES[1]

1. Barrows, William Morton. *Science of Animal Life.*
   a. The Protozoa, pp. 17–166
   b. The Coelenterates, pp. 167–176
   c. Echinoderms, pp. 176–178
   d. Worms, pp. 181–198
   e. Mollusks, pp. 205–218
   f. Arthropods, pp. 218–247
   g. The backboned animals, pp. 247–294

[1] The pages listed here are those found in the editions indicated in the alphabetical list of references given at the end of this book.

2. Clark, Austin H. *Nature Narratives.*
   a. A creature of mystery—the eel, pp. 22–25
   b. Some interesting sharks, pp. 42–45
   c. Animal lilies, pp. 121–124
3. Crowder, William. *A Naturalist at the Seashore.*
4. Ditmars, Raymond Lee. *Reptiles of the World.*
   a. Turtles and tortoises, pp. 3–63
   b. Crocodiles and alligators, pp. 63–91
   c. Lizards, pp. 91–195
   d. The snakes, pp. 195–359
5. Robbins, Wilfred W., and Isenbarger, Jerome. *Practical Problems in Botany.*
6. Rolfe, R. T. and F. W. *Romance of the Fungus World.*
7. Thomson, J. Arthur. *Biology for Everyman.*
   a. Each phylum of animals in detail, pp. 3–656
   b. Each phylum of plants in detail, pp. 1021–1252
8. Transeau, Edgar Nelson. *Science of Plant Life.*
   a. The algae, pp. 234–249
   b. The fungi, pp. 249–272
   c. The liverworts and mosses, pp. 272–283
   d. The ferns, pp. 283–294
   e. Seed plants, pp. 294–318
9. Ward, Frances Kingdon. *Romance of Plant Hunting.*
   a. Plant hunters and plant hunting, pp. 14–32
   b. Plant hunting on the cliffs, pp. 170–191
10. *The Book of Popular Science.*
   a. The snake tribe, Vol. 12, pp. 3921–3934
   b. The plants of the sea, Vol. 14, pp. 4631–4640
11. *Compton's Pictured Encyclopedia.*
   a. The classification of plants—outline, Vol. 2, p. 205
   b. The classification of animals—outline, Vol. 15, pp. 227–231
12. *Nature Magazine.*
   The monthly issues of this magazine frequently contain excellent articles related to this unit.
13. *New Wonder World, The.*
   a. Plants and animals of the sea, Vol. 1, pp. 209–258
   b. The classification of animals, Vol. 3, pp. 145–147
14. *World Book Encyclopedia, The.*
   a. The classification of plants—outline, Reading and Study Guide, pp. 8099–8105
   b. The classification of animals—outline, Reading and Study Guide, pp. 8479–8487

VISUAL AIDS

FILMS[1]

A. Erpi Picture Consultants, Inc., 250 West 57th Street, New York City.
   1. Animal Life. 1 reel, sound, $50.00.
      Presents an interesting review of the various phyla of the animal kingdom
B. Harvard Film Service, Cambridge, Massachusetts.
   1. Fern. 20 reels, silent, $25.00.
      Develops the life cycle of the fern and shows various types of ferns
C. Y. M. C. A. Motion Picture Bureau, New York City.
   1. Fruits and Flowers. 1 reel, silent, rental.
   2. Down at Our Pond. 1 reel, silent, rental.
   3. Gathering Moss. 1 reel, sound, rental.
D. University of Kansas, Lawrence, Kansas.
   1. Cat Animals. 1 reel, silent, 50c per day.
   2. Corals. 1 reel, silent, 50c per day.
   3. The Sea Urchin. 1 reel, silent, 50c per day.
E. Indiana University, Extension Division, Bloomington, Indiana.
   1. The Snake's Life. 1 reel, silent, $1.00 per day.
   2. The Life Cycle of the Frog. 1 reel, silent, $1.00 per day.
   3. The Snail. 1 reel, silent, $1.00 per day.
   4. Who's Zoo? 1 reel, silent, $1.00 per day.
      Makes a study of various animals at a zoo

CHARTS

Series	*Titles*
A. J-K-Q Botany Charts	Algae; Mold; Yeast; Lichen; Liverworts; Pine; Pea
B. Schmeil Botany Charts	Wheat Rust; Gill Mushrooms; Pore Mushrooms; Fern
C. Pfurtscheller Zoölogy Charts	Sponge; Hydra; Tapeworm; Coelenterates; Earthworm; Starfish; Spider; Crayfish; Centipede; Snail; Clam; Perch; Frog; Pigeon; Rat
D. Balslev-Anderson Chart	Insects

[1] Reread slide and film suggestions in Unit One.

UNIT EIGHT

ON NATURE'S TRAILS

SUGGESTIONS TO TEACHERS

One of the fundamental aims of education is to provide a suitable background for the worthy use of leisure time. Students should come to realize that they cannot afford to spend their leisure time in idleness. The greatest pleasure comes from its profitable employment. It is the purpose of this unit to stimulate interest in nature and the great outdoors to the end that students will take a keen delight in studying the mysteries of life in its wide variety of forms. Furthermore, exercise in the open is one of the greatest requisites for good health and good living.

The biology of this unit lies in the observation and identification of fish, birds, fur-bearing animals, wild flowers, and trees. It is hoped that a study of these forms of life will lead the student out to forest, field, and stream, where the various forms actually grow and live. As a teacher, you can do much to bring about the making of many pleasurable field trips. The following objectives will guide the work of the unit as it progresses.

OBJECTIVES

I. Facts and principles

A. To learn the names of and means of identifying:
1. Some of the common fish
2. Some of the common birds
3. Some of the common fur-bearers
4. Some of our showy wild flowers
5. Some of our greatest trees

B. To learn about the wily nature of fish, birds, and fur-bearers, thereby adding zest to the study of them

II. Attitudes

A. To develop an appreciation of nature and the life there is about us

B. To stimulate a desire to help in the conservation of wild life

C. To develop an understanding of what it means to be a good sportsman

UNIT EIGHT

ON NATURE'S TRAILS

A FRIEND OF NATURE—THE BAREFOOT BOY

A boy such as this fully understands the meaning of the following poem.

THE BAREFOOT BOY

PREVIEW

Knowledge never learned of schools,
Of the wild bee's morning chase,
Of the wild flower's time and place,
Flight of fowl and habitude
Of the tenants of the wood;
How the tortoise bears his shell,
How the woodchuck digs his cell
And the ground-mole sinks his well;

THE LURE OF NATURE

What could be more beautiful than a peaceful scene like this?

How the robin feeds her young,
How the oriole's nest is hung;
Where the whitest lilies blow,
Where the freshest berries grow,
Where the ground-nut trails its vine,
Where the wood-grape's clusters shine;
Of the black-wasp's cunning way,
Mason of his walls of clay,
And the architectural plans
Of gray hornet artisans.

Thus Whittier in a famous poem calls attention to much that may be learned in the great outdoors. Note the words "Knowledge never learned of schools" and apply the thought to your own experience. You have been studying about various

forms of life in classroom and laboratory, but how much do you know about life as it actually exists? Do you know how the oriole's nest is hung or how the ground-mole sinks its well? Do you know the wild flower's time and place? Reread the foregoing lines and use them as a test to find out how much you really know about the simple forms of life in the community round about you.

If you have never come to think, in some measure, of nature as a great teacher and have never seriously thought of the wonders and beauty of life, then you have missed a part of the real joy of living. Every species of plant and animal has a story all its own—a real romance if you but delve into the part it plays in the great scheme of life. It is the purpose of this unit to help you learn more about life as it actually exists and to appreciate more fully your natural environment. To this end you will be asked to follow some of nature's trails, to find out where they lead, and what they reveal. The following problems are submitted for your guidance.

PROBLEMS

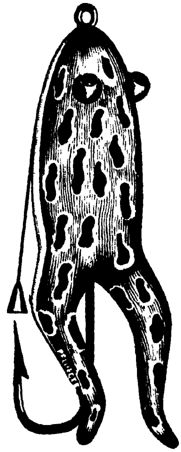
1. **What are the characteristics of some interesting fish?**
2. **Why may birds be considered friends of man?**
3. **What are the haunts and habits of fur-bearers?**
4. **What are some of the wonders of wild-flower land?**
5. **Why and how should we become acquainted with our trees?**

Problem 1. What are the characteristics of some interesting fish?

It has been frequently said that a good fisherman must have great patience; and indeed he must, but that is not all. Far more important is the fact that he must know fish, how and where they live, and much about their habits. Fishing, then, does not consist merely of waiting on the banks of a stream

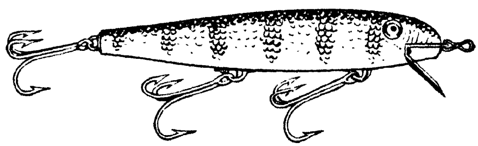
ARTIFICIAL BAITS OF PROVED VALUE

1



2

3



5

Courtesy Pflueger Pocket Catalogue, by permission of the copyright owners

4

1. The pork rind imitates a worm and is effective for all game fish.

2. The artificial frog is a close imitation of a living frog. If it is kept on the move, it will prove an excellent lure for bass, pike, pickerel, and even the big muskellunge.

3. The spinner is very effective bait for all game fish, especially bass. The flash of the spinner as it revolves in the water catches the eye of the bass, causing it to strike.

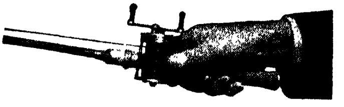
4. The trout and bass flies so closely imitate living insects that they successfully attract the attention of the fish.

5. The imitation minnow is a wooden plug especially good for pike.

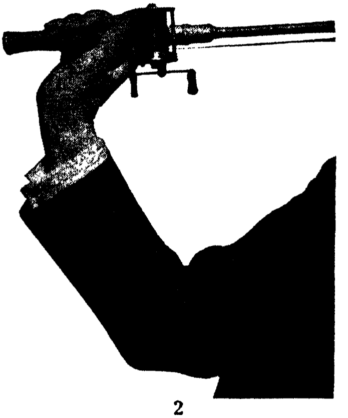
with a pole in hand, hoping for luck. Success in fishing comes only from the application of definite methods that are based upon an understanding of the behavior of the fish to be caught. This is true in all types of angling, whether we fish for tiny minnows or for some of the great sea monsters, such as sharks or whales. A good fisherman is usually a good naturalist, so far as an understanding of fish is concerned.

It is clearly impossible to establish definite rules to be followed in angling, but certain tips will be helpful. The following list has been drawn up from the experience of a great number of anglers.

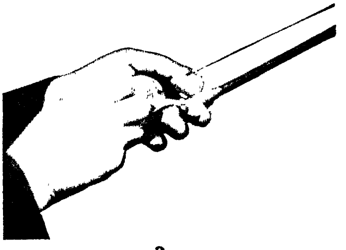
STEPS IN OVERHEAD BAIT CASTING



1



2



3

Courtesy Pflueger Pocket Catalogue, by permission of the copyright owners

1. Aim the tip of the rod at the target.
2. Raise the rod over the right shoulder. Bring the arm down quickly in order to carry the bait toward the target. Release the bait as rapidly as possible without tangling the line.
3. Reel in the bait rapidly to attract the attention of the fish.

Tips to Anglers

1. Specialize on certain kinds of fish; that is, learn all you can about a few species. Doubtless you will want to select those most common in the community where you live.

2. Study different types of fishing tackle so as to be able to choose those best adapted to the species you want to catch.

3. When you are using a natural bait, give a fish time to swallow it before pulling in the line. The time required will depend upon the feeding habits of the fish. If an artificial bait is used, reel back the line the moment it enters the water. The reeling should be done at great speed.

4. Never pull on a fish buried in seaweed or grass, as there is danger of breaking your line. The best method is to hold the line tight and let the fish dig or wiggle its way out.

5. Always string your fish through the upper lip rather than through the gills, as they will live longer by this method. If the fish are killed, cover them with moist moss, water grasses, or a gunny sack. This is especially necessary under a hot sun.

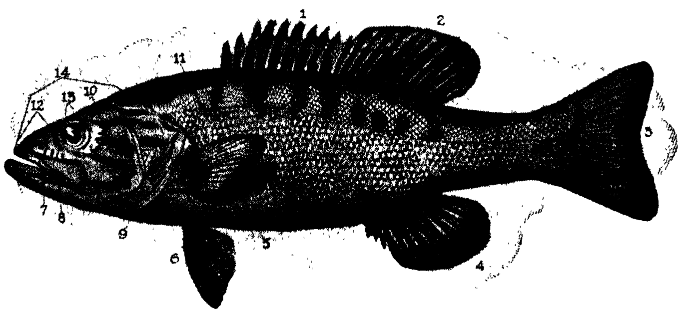
6. Never *bait-cast* or *fly-cast* with three or more in a boat. Someone is likely to get severely hooked and may lose an eye.

7. If you use natural bait, you will probably get best results if you fish when the wind causes slight ripples on the water.

8. Be a true sportsman; that is, do not needlessly destroy life; and always conform to the law in respect to the size of your catch.

9. Be thoroughly posted regarding the fish and game laws of the state or region where you fish.

EXTERNAL PARTS OF A FISH



Courtesy *World Book Encyclopedia*

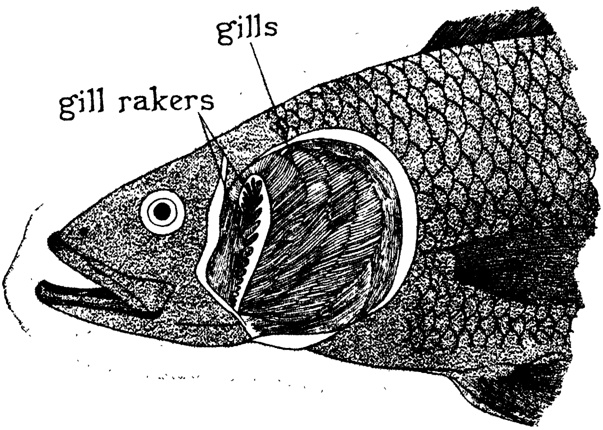
1. First dorsal fin
2 Second dorsal fin
3. Caudal fin
4. Anal fin
5. Pectoral fin
6. Pelvic fin
7. Lower jaw
8. Upper jaw
9. Operculum (gill cover)
10. Pre-opercle (cheek)
11. Lateral line
12. Nose
13. Eye
14. Head

THE FASCINATING LIFE OF FISH

Fish are found in most bodies of water, such as lakes, rivers, and oceans, where there are sufficient oxygen and plant life for their existence. They are so common in our environment that we are doubtless acquainted with their general characteristics, but we shall pause to review the more important ones briefly before proceeding to a discussion of particular species.

The outside of a fish. Typical bony fish are easily recognized by *scales* imbedded in their skin. These scales overlap much as do the shingles on a roof and serve as a protective covering. For locomotion, fish are greatly dependent upon *fins*, which are thin membranes supported by stiff spines or by rods of cartilage. Just back of the head are *pectoral* fins, and farther back

THE GILLS AND GILL RAKERS OF THE FISH



Water enters the mouth and passes out over the gills at the sides of the body. Minute particles are strained out by the gill rakers and retained as food.

and lower down on the sides of the body are the paired *pelvic*, or ventral, fins. These paired fins serve as paddles for propelling the fish along. When they are extended at right angles to the body, they act as brakes. The single fins are the *dorsal* (usually there are two), *anal*, and *caudal*, or tail, fin. The dorsal fin or fins help a fish balance itself, the anal helps it steer itself, and the caudal gives it power of locomotion.

Sense organs of the fish. The *nostrils* consist of two openings just in front of the eyes. Particles in the water come into contact with the sense organs in the nostrils and cause the sensation of smell. Since the nostrils are not used for breathing, they have no connection with the throat. The *eyes* are large and round, without lids, and are somewhat movable. The

ears, which are so deeply imbedded in the skull that they cannot be seen, merely detect vibrations. Some authorities think that they also serve as balancing organs.

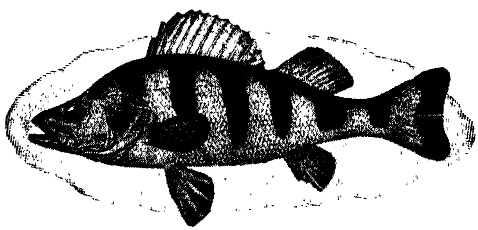
How a fish breathes. A fish breathes by means of two sets of *gills*. These are thin, feathery, red structures located on each side of the head. As water enters the mouth, it passes over the gills and some of its oxygen diffuses into the blood. At the same time, some of the carbon dioxide from the blood diffuses into the water. In most common species of fish the gills are covered with a tough movable flap called the *operculum* (ō-pûr'kū-lŭm), which protects the delicate gill filaments.

How a fish gets food. A fish usually eats smaller forms of aquatic life. Some fish seize and hold these organisms with their teeth. Other fish have no teeth or only poorly developed ones and depend almost entirely upon *gill rakers*. These gill rakers strain out food or small organisms from the water as shown in the illustration on the preceding page. For details on the food tract of a fish turn to page 241.

Real Fish Stories

A fish for the beginner—the yellow perch. One of the best known fresh-water fish is the yellow perch, often called a good

EASILY CAPTURED FISH—THE YELLOW PERCH

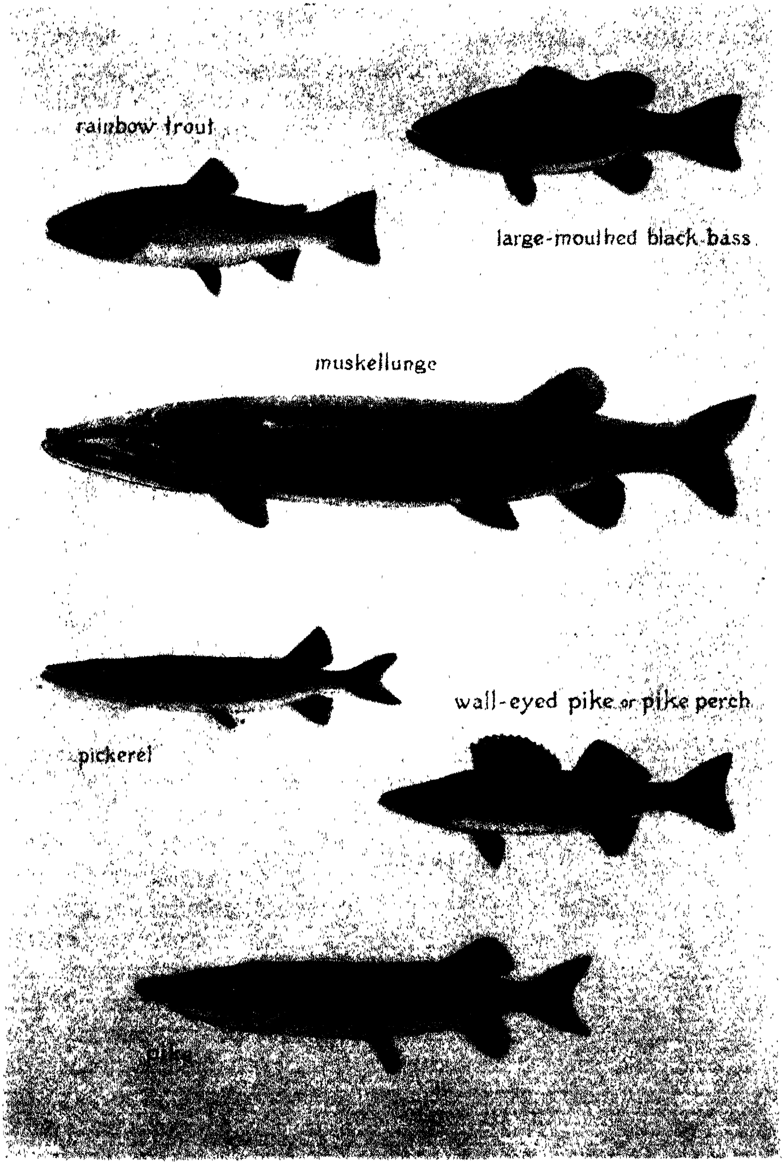


Courtesy Pflueger Pocket Catalogue, by permission of the copyright owners

This fresh-water fish is attracted by almost any kind of bait. According to record, the largest yellow perch ever caught with fishing tackle weighed 5⅛ pounds.

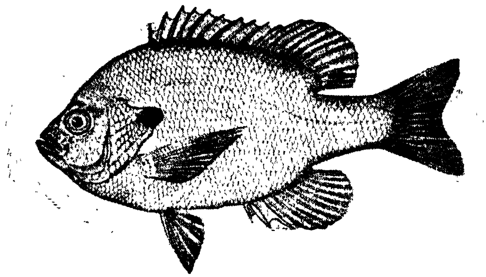
fish for beginning fishermen because it is so easy to catch. The perch can be caught with a hook and line at almost any time of the year, even through a hole in the ice in winter.

SOME OF OUR NORTH AMERICAN FISH



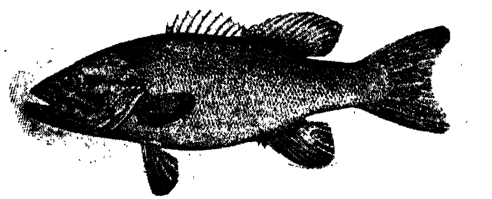
Grasshoppers, angleworms, minnows, or pieces of fish are tempting bait. The yellow perch lives in the Great Lakes, in fresh streams and inlets of the East, and in streams and lakes of the upper Mississippi Valley.

ANOTHER FISH FOR THE BEGINNER—THE BLUEGILL



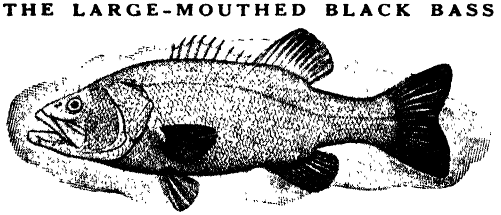
This little fresh-water bluegill is a member of the sunfish family. Nearly every angler enjoys catching this fish, because it possesses many fighting traits.

THE SMALL-MOUTHED BLACK BASS



This fish prefers deeper and cooler waters than does the large-mouthed black bass shown in the picture below. It is very interesting in that the male prepares the nest, digging a hole in the sand with its snout.

THE LARGE-MOUTHED BLACK BASS



Courtesy Pflueger Pocket Catalogue, by permission of the copyright owners

This bass is larger in every way than the small-mouthed variety. The average weight is from two to three pounds. When you hook your first one, you will probably think, however, that it is much heavier.

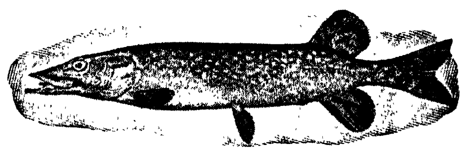
This perch is a small fish, usually from eight to twelve inches in length. The upper part of its body is olive green in color; its sides are golden yellow marked with broad dark stripes; its belly is white; and its lower fins are largely orange or red. Other names by which the yellow perch is known are raccoon perch, American perch, striped perch, and red perch.

For the experienced angler—the black bass. There are two species of black bass, the small-mouthed bass and the large-mouthed. Both

species are favorites with expert fishermen, for they put up a strong battle when hooked. One experienced angler says of the black bass, for example, that, "inch for inch and pound for pound, it is the gamest fish that swims."

The black bass of both species normally makes its home in a clear, running stream or clear, cool lake, but it is hardy and can adapt itself readily to almost any environment. It varies greatly in size, the small-mouthed species seldom weighing more than six pounds, and the large-mouthed species weighing as much as fourteen pounds. The general color of both species is the same, a dull golden green with bronze luster. Along the sides are dark spots which tend to form short vertical bars. In general, its markings give it a streamlined effect.

A FAMOUS GAME FISH—THE NORTHERN PIKE



Courtesy Pflueger Pocket Catalogue, by permission of the copyright owners

Although this is a fairly large game fish, it is much smaller than the muskellunge, which it closely resembles. The presence of the northern pike attracts many fishermen to northern inland lakes.

The prize of the fly-fisherman—the trout. There are several species of trout, of which the best known is the speckled trout of the East and the rainbow trout of the West. These two species, though rather small, are the most highly prized by anglers. They live only in clear, cool, shady waters, and are usually caught with imitation insects, known as flies.

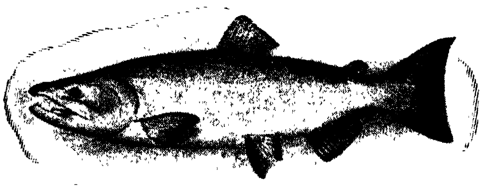
The fly-fisherman is the most skillful of anglers. In hip boots, he wades up a stream, armed with a light, flexible rod bearing a long line with a fly at the end. He knows exactly where to drop the fly in order to attract a fish. He must use skill and judgment, however, for the trout is a fighting fish and will try desperately to escape when caught.

The Great Lakes trout. The Great Lakes trout grows to a large size and is an important food fish. The average weight of this fish is eighteen pounds, but occasionally a trout weighing over one hundred pounds is caught. Since it is large, it is not caught with a fishing rod and line but in a gill-net. Although

the Great Lakes trout eats both plants and animals, it seems to prefer lake herring, which are plentiful in its habitat.

A fish from the Gulf of Mexico—the red snapper. Because of its name we might think of the red snapper as a red colored fish, but it is really more rose colored than red. It is found in the Gulf of Mexico, usually well out from shore. As a catch it is highly prized, because its pink flesh makes excellent food and has a ready market in many parts of the country. Sometimes a single fish weighs as much as twenty-five pounds. Although it is caught largely for commercial purposes, it also furnishes great sport for fishermen. Many deep-sea fishermen feel that their experience is not complete until they have fished for the red snapper in the warm waters of the Gulf.

THE FAMOUS CHINOOK SALMON



Courtesy Pflueger Pocket Catalogue, by permission of the copyright owners

This is the largest species of salmon. How a fisherman likes to catch one of these fish! One fisherman claims to have caught a 108-pounder with a hook and line.

A fish that battles for its life—the salmon. The salmon is born in the headwaters of streams, principally in the northwestern part of the United States and in Alaska. When it is about two years old, it forsakes its old home and goes to live in the sea. Its habits at sea are hard to observe, but it probably doesn't travel far from the mouth of the stream where it has lived. After living in the salty water for about two years, it swims up the stream again toward the headwaters to *spawn,* or lay eggs. When it comes to waterfalls, it leaps up the falls into the higher waters. Nothing but death seems to prevent it from reaching its old home.

When the salmon reaches the end of its perilous journey, it at once begins to spawn. Each female deposits a large number of eggs on beds of fine gravel in the bottom of the stream. The male then spreads sperm cells or "milt" over the eggs to fertilize them. When they have completed this

SALMON LEAPING UP A WATERFALL

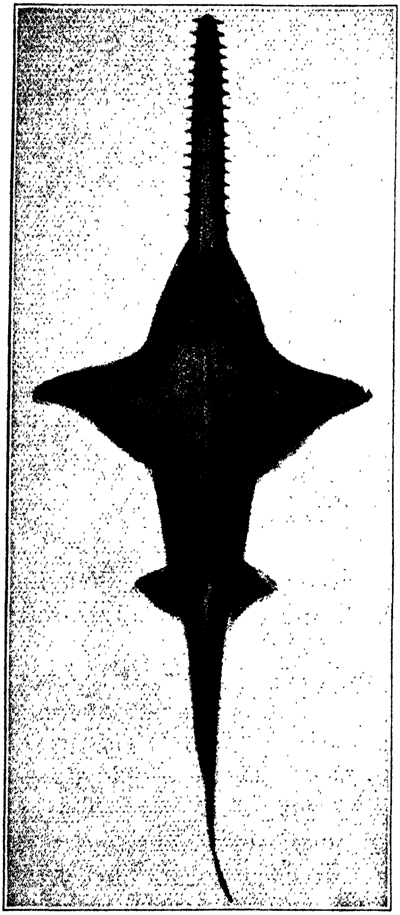
Going downstream over a falls is easy for most water animals, but only the salmon is able to leap up a waterfall. Sometimes it leaps several feet almost straight in the air.

process, both of them die. What a tragic end after they have battled against such heavy odds to reach a suitable place to perpetuate their kind!

Of the different species of salmon the sockeye, or blueback, is the most numerous. It is a medium-sized fish averaging about five pounds and is most abundant in the waters of Alaska. The largest species is the chinook, or king, found around Puget Sound and in the Columbia River. This fish averages twenty to twenty-five pounds in weight, but sometimes weighs as much as a hundred pounds. The salmon is an important fish commercially and has a very wide sale.

A swashbuckler of the sea—the swordfish. The swordfish, as its name indicates, is armed with a long sword. Protected in this manner, it is a champion duelist and one of the boldest animals of the sea. Indeed, it fears no living thing, not even man. If a boat happens to cross its path, it may pierce the bottom, causing it to sink and throwing consternation into the hearts of the occupants.

FISH THAT ANGLERS ARE CAREFUL TO AVOID



This dangerous fish has often thrown fear into the hearts of men by sawing a hole through the bottom of a boat.

The swordfish is shaped like a mackerel, but sometimes grows to a length of ten to fifteen feet, weighing as much as six or eight hundred pounds. Its sword is a flattened and tapering projection which appears to be a continuation of its upper jaw. With this sword it makes a swift rush at its prey or enemy, attempting to pierce the body. It will even attack whales, octopuses, or giant squids and is seldom the loser in a fight. Of all the swordfish, the broadbill is the chief prize of sea fishermen, because it affords the greatest danger and excitement.

Another fish somewhat like the swordfish is the sawfish, so named because it has a saw-like blade on its upper jaw. Though it resembles the swordfish, it belongs to an entirely different family. It puts up a bitter fight and is a choice prize of sea anglers.

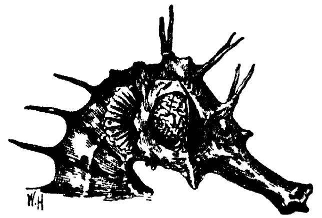
The terror of the sea—the shark. From ancient times the shark has been dreaded as a ferocious monster of the sea. This strange creature is a kind of fish, but its skeleton consists of tough cartilage, rather than of bones. Its body, too, is covered with a thick hide rather than with scales. This hide contains small flinty particles that make

the surface rough like that of sandpaper. Most sharks are very powerful and are among the swiftest swimmers of the seas. They hunt near the surface. Since their large mouths are located on the ventral side of their bodies, they usually turn on their backs to seize their prey. They crush the prey between rows of sharp-pointed teeth firmly set in their powerful jaws and, of course, make quick work of consuming it.

Some sharks, referred to as ground sharks, are sluggish and blunt-headed. These ugly creatures hunt near the bottom of shallow water for their food. They live largely on sea anemones and various types of shellfish.

An odd fish — the sea horse. The curious little sea horse bears slight resemblance to ordinary fish, for it has a head like a horse and a tail like a snake. It has no definite home, but is found in nearly all of the warm and temperate seas. It swims upright by means of a single back fin. Its body is covered with bony plates and spines that harmonize with the color of the weeds among which it lives. For food it sucks up tiny animals and fish eggs through its long slender snout. The most peculiar thing about the sea horse, aside from its unusual appearance, is the fact that the male carries both the eggs and the young in a pouch.

A HORSE-LIKE CREATURE
THE SEA HORSE

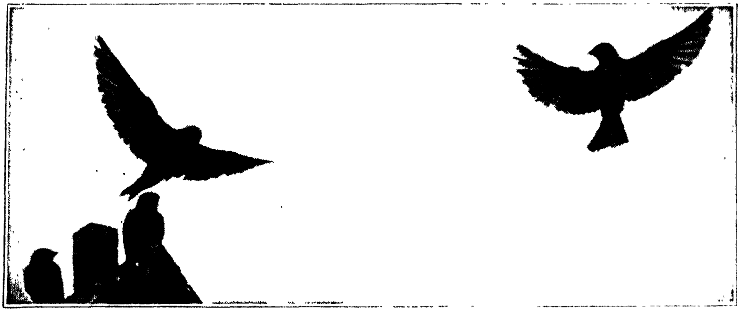


Enlarged about three times

After Schmeil

The upper figure shows the head and gills of the sea horse. The lower picture shows the creature as it appears among the seaweeds. Note that it swims in an upright position by means of a single fin at the back. When it wishes to hide, it twists its tail about a seaweed.

PURPLE MARTINS IN FLIGHT



Courtesy Cleveland Museum of Natural History

These birds prefer to live in "apartment" houses with separate little rooms for each family. In the early fall they gather in great flocks for their trip to the South.

Problem 2. Why may birds be considered friends of man?

Birds, through their bright plumage, beautiful songs, and ways of living, have long appealed to the interest and imagination of mankind. Many people, both old and young, take great pleasure in familiarizing themselves with the birds of their respective localities. If we truly want to follow some of nature's trails, there is no better way than to follow certain birds to their homes, to listen to their songs, and to observe their ways of living.

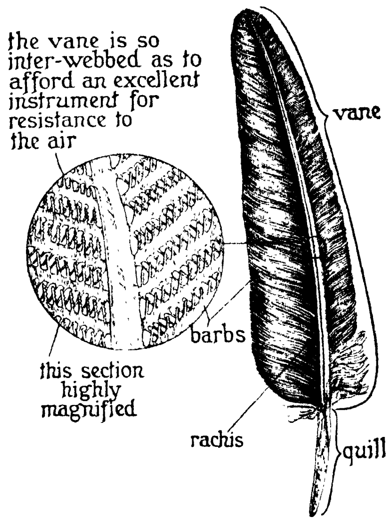
GENERAL CHARACTERISTICS OF BIRDS

Birds differ from all other classes of vertebrates in that they bear feathers and their forelimbs are developed as wings. Their beaks or bills consist of two horny, toothless jaws. They are warm-blooded animals, their temperature being higher than that of mammals. Their feet are peculiarly adapted to walking, perching, or swimming. All birds are *oviparous* (ō-vĭp′ȧ-*rus*); that is, their young are hatched from eggs. Most birds are attractively colored and marked, the females having less brilliant colors than the males.

How the bird is built for flying. Birds are distinctive in activity because of their ability to fly. For an understanding

of this ability let us consider the feathers, wings, and skeleton of a bird. The feathers are developed from sacs in the skin like the scales of reptiles and the hair of mammals. The larger feathers, known as quill feathers, consist of a hollow portion, the *quill*, and an expanded portion, the *vane*. Most of the larger feathers are on the wings and tail of the bird.

HOW THE FEATHER AIDS IN FLIGHT



The feathers on a bird's wings are strong and light. Moreover, they are so constructed that they offer strong resistance to the air.

The wings get their power from strong muscles extending from the breast. When the bird is flying, the wings are raised over the body, then brought downward and backward. The downward strokes raise the body of the bird or support it, and the backward strokes move it ahead. The steering apparatus includes both the wings and the tail. When a bird chooses, it "shuts off its motor," circles about, and descends, without a stroke of the wings. The ease with which it handles itself is enthralling.

Most of the bones in a bird are hollow and filled with air spaces. This structure tends to make them both strong and light. Furthermore, the head and tail, wings and feet are very light, only the trunk having much weight. Thus a bird is helped in flying by both the structure and the arrangement of its parts.

Feet for all purposes. In the form and structure of its feet, a bird shows remarkable adaptations to environment. Most of these adaptations are related to flying and to the catching and handling of food. The table on the following page shows what some of these adaptations are.

Special Adaptations of a Bird's Feet

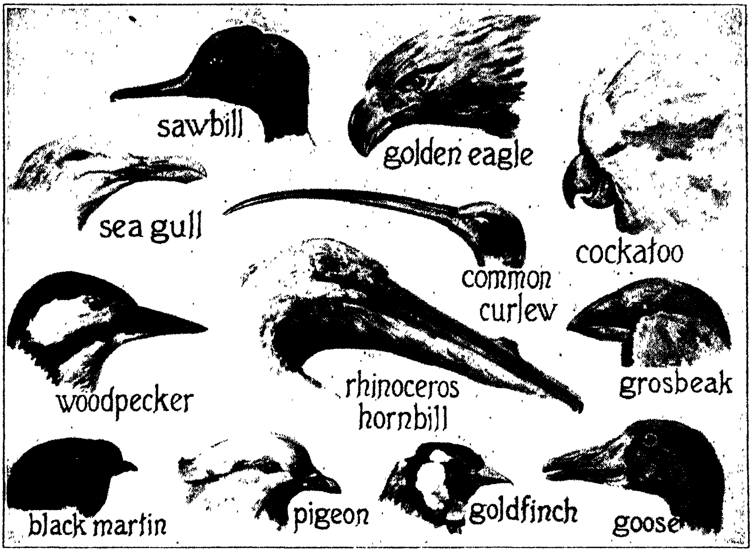
Special Purpose	Foot Structure	Example
To swim..	Webbing between the toes	Duck
To wade..	Long legs with four long slender toes all on the same level	Heron
To climb..	Two front and two back toes ending in sharp claws	Woodpecker
To perch..	Three toes in front, one at the back. Foot locks to a perch by automatic action of certain tendons	Pigeon
To scratch	Three toes in front, one at the back, all ending in strong, blunt claws	Chicken
To prey...	All toes equipped with curved sharp claws	Fish hawk
To fight...	Sharp spurs on the feet	Rooster—the male of the common barnyard fowl

A bird's "kit of tools"—the bill. Since the bird has wings, it has no pectoral appendages such as those of the mammal. Therefore it has learned to use its bill for a great many purposes. As a result, we find a wide range of variations in size, form, and structure. There seems to be a bill for almost every purpose imaginable.

The pet canary uses its bill as a comb and brush. It presses on an oil gland at the root of its tail and gives itself a neat shampoo. The woodpecker, besides using its sharp bill for digging a hole, often uses it as a musical instrument. Perched on a resounding limb or pole, it beats a tattoo to its mate much as a lover serenades his sweetheart with a guitar. An owl, when frightened or angry, brings the upper and lower parts of its bill together with a snap similar to that of castanets, sometimes used in an orchestra.

Bills take on the greatest variations in nest-building and food-gathering. In nest building, for instance, a bill may serve as a needle, a trowel, a chisel, or an auger. The long, weak bill of the hummingbird is useful for catching insects, whereas the broad, flat bill of the duck is useful for skimming and straining minute organisms from the surface of the water. The table on the following page shows some of the variations in bills that make them suitable for a wide variety of purposes.

BEAKS FOR MANY PURPOSES



Matzdorf Structural Zoölogy Chart
Courtesy A. J. Nystrom & Company

SPECIAL ADAPTATIONS OF BILLS

SPECIAL PURPOSE	BILL STRUCTURE	EXAMPLE
To bore into bark	Chisel-shaped	Woodpecker
To tear flesh of prey	Sharp and hooked	Eagle
To gather nectar from flowers with long tubes	Long and slender, often longer than the body	Hummingbird
To dig into mud	Probelike	Woodcock
To catch fish	Long, pointed, and javelin-like	Kingfisher
To feed on seeds	Short and powerful	Cardinal
To sift food from water	Broad, flat, and sensitive	Duck

Strong senses of sight and hearing. Most birds have ordinary senses of touch, taste, and smell, but they have remarkable senses of sight and hearing. A vulture soaring aloft, for example, can see food on the ground hundreds of feet below. A shrike or butcher bird, resting on top of a telephone pole, can fly straight to a grasshopper fifty feet below in the grass. A fish hawk flies about searching for

prey two hundred fifty feet from the ground. A sparrow hawk rests high above the ground as it watches for mice in the fields. Many birds, such as the owl, have such good vision that they can hunt at night. Usually, however, they hunt such larger forms of life as mice and rats.

Several instances may also be cited to show that birds have a strong sense of hearing. The white egret off the Keys of Florida leaves its nest when a shotgun is fired a mile and a half away. A barred owl will turn its head in response to faint noises one hundred fifty feet away. It is even believed that a woodpecker listens for larvae boring under the bark of a tree and that a robin cocks its head to listen for the movement of earthworms.

How birds express themselves. Many people think that birds merely "sing," but they really have two ways of expressing themselves, through song notes and call notes. The song notes usually have some relation to mating, whereas the call notes make up the everyday language of birds. Singing is commonly restricted to the male for effectively wooing his mate. The real song period comes in the spring and corresponds more or less closely with the mating season. Some species, however, such as the wood pewee, indigo bunting, and red-eyed vireo, sing throughout the year. The songs of some birds, such as the chickadee, cardinal, field sparrow, and oriole, closely resemble a man's whistle. Consequently man often imitates these birds, and does it so effectively that he may deceive even the birds themselves.

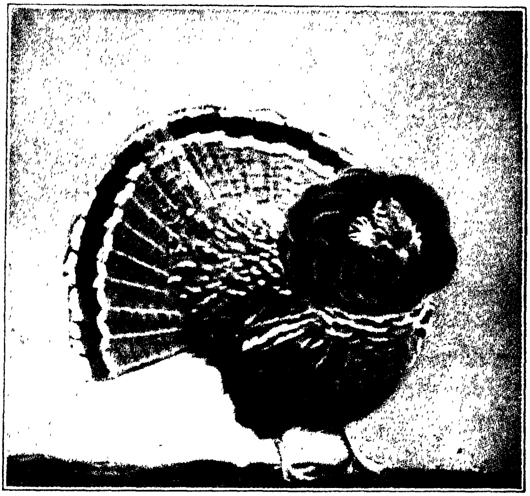
The call notes of birds are more interesting than are their songs. By listening to the call notes of robins, crows, and barnyard fowls, we shall find that they can give forth expressions of contentment, fear, suspicion, alarm, and hunger. Peculiarly, some of the call notes, such as those of "distress" and "rally," seem to be understood by all species.

FAMILY HABITS OF BIRDS

Courtship and mating. When the mating season approaches, the male begins activities by choosing a certain territory or

"homestead" as his own. Then he spends most of his time in the territory, driving away every other male of his species. Later, when a group of females arrives, he begins a carefully mapped program to persuade one of them to accept the territory he has chosen and is so bravely defending. His program may include singing, displaying plumage, strutting, even fighting. Finally one of the females accepts his offer, and the others fly away to other surroundings.

THE RUFFED GROUSE ON A DRESS PARADE



Eastman Teaching Films, Inc.

The male grouse courts the hen by strutting up and down on a log and by "drumming" with his wings.

Choosing a site for a home. It is the female that selects the exact site for a nest and actually does most of the building. The male occasionally makes a pretense of helping, but does not seem to know what kinds of materials to collect or the methods of putting them together. His special duty seems to be that of preventing intrusion by other birds. He also acts somewhat as a general overseer, making an occasional suggestion. The first consideration in choosing a site for a nest seems to be concealment. In spite of this care, many nests are broken up and destroyed. The maternal instinct, however, is so strong that a female will if necessary build several nests in which to lay eggs and rear her young.

Constructing the home. Different species of birds use different materials for building nests. Most of them have certain characteristics which they observe. In general, they use

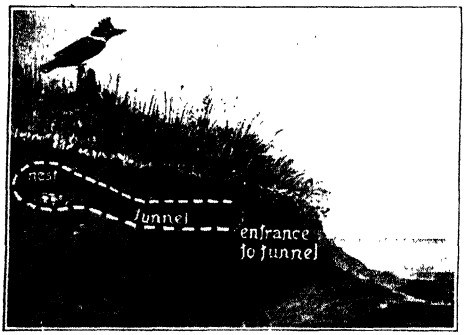
grasses, twigs, and small roots. Many, however, use leaves, bark, hair, feathers, rags, clay, paper, and any other materials that they may find in their environment.

THE NEST OF A HAWK

Lynwood M. Chace

These downy little birds are baby Cooper's hawks awaiting their mother's return with a tender young chicken. Observe how crudely the nest is built of twigs.

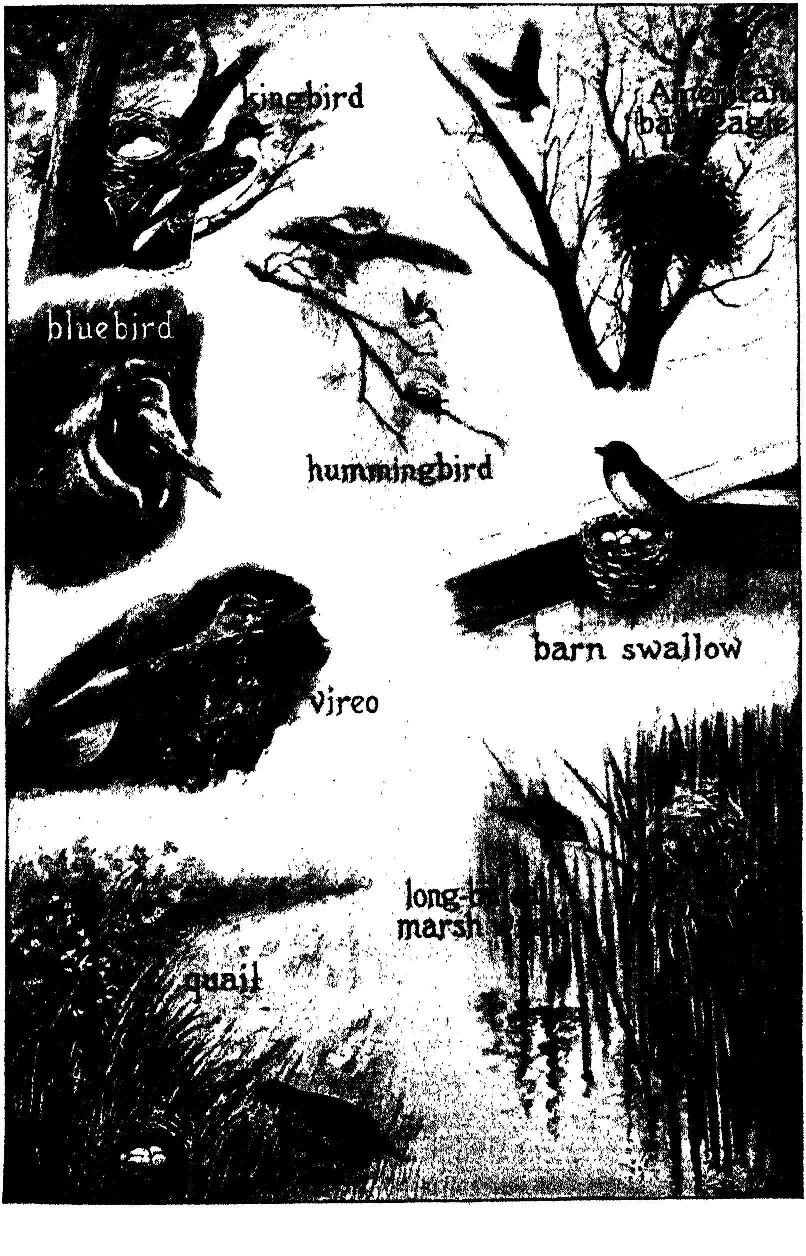
A KINGFISHER'S NEST



The white dashes show the tunnel which the kingfisher builds in the bank of a stream. Only the entrance, of course, shows from the outside.

Birds are popularly classified, according to the manner in which they build their nests, as masons, carpenters, felters, weavers, molders, and tailors. The best builder of nests, perhaps, is the oriole. Other birds, such as the whippoorwill, build no nests at all. Between the oriole and the whippoorwill there is a wide range of artisans. The killdeer scoops out a little depression in the ground to keep the eggs from rolling about. Usually it also lines the depression with pebbles to keep the eggs from sticking in the mud. The mourning dove builds a crude platform of sticks, barely sufficient to keep its eggs in place. The crow and catbird use sticks, but build deeply hollowed nests and line them with softer materials. The chimney swallow also uses sticks, but it binds them together with a sticky saliva that hardens into a strong glue. The kingfisher, after excavating a two- or three-foot tunnel in the bank of a river, lines an enlarged chamber

COMMON BIRDS WITH THEIR NESTS



at the end with skeletons of fish, frogs, and other prey. The cowbird is merely a trespasser. It builds no nest of its own, but slyly deposits its eggs in another bird's nest and even leaves the care of its young to the other bird.

Making use of the home. The mother bird, of course, uses the nest as a place for laying eggs. The size and number of eggs laid depend entirely upon the species. A small bird usually lays smaller eggs than a large one, but not always. The eggs of the tiny hummingbird, for instance, are about the size of a navy bean, and those of an ostrich are about the size of a grapefruit. The meadow lark lays small eggs, but the upland lark, which is about the same size and weight, lays much larger ones.

THE USUAL TYPE OF NEST

Ewing Galloway

The usual bird's nest is made of grass or straw. It generally contains four eggs. This picture shows the four eggs ready for a period of incubation.

The average number of eggs laid by birds in temperate regions is four, but the average for birds of the tropics is two. The greater number of eggs in temperate regions doubtless has a relation to the greater element of danger involved in hatching. The element of danger also seems to have a bearing on the number of eggs laid by sea birds, some laying but one egg on a well-protected cliff. In contrast, the quail, which builds its nest on the ground, may lay as many as twenty eggs. Birds that risk losing their eggs usually lay fairly large numbers.

The period of incubation, with few exceptions, seems to depend on the size of the egg. It varies from ten days in the

case of the cowbird to fifty or sixty with the ostrich, and even to seventy or eighty with the emu. In most species the female assumes the responsibility for incubation, but in others the male and female share equally in the work. In a few interesting species, the male takes over the entire task of incubation.

HUNGRY MOUTHS

L. W. Brownell

A young robin commonly consumes two to three feet of worms in a day. Every time the mother bird appears, the hungry creature is ready to be fed.

Rearing the young. Birds hatched in nests on the ground usually are wide awake and soon follow their parents in search of food. Those hatched in the trees, on the contrary, are less fully developed and must be fed for a longer period of time. Few human parents give greater care to the feeding of infants than do birds to the feeding of helpless nestlings. Some birds, such as the mourning dove and the goldfinch, feed by *regurgitation;* that is, the parent bird swallows the food, returns it to the mouth, and gives it to the young in a partially digested state.

Teaching and protecting the young. As a rule the parent bird is rather impatient in teaching the young. As a matter of fact, the young need few lessons, but seem to know by instinct about what they should do. When it comes to protection of the young, a parent is unusually alert. It may pretend it is wounded and drag a leg or a wing pitifully over the ground, hoping the enemy will follow and thus lose track of the nest. Again, it may become very militant and dart at the enemy, using its bill or claws as weapons of attack.

THE MIGRATION OF BIRDS

The reason for migration of birds is not definitely known. Various theories have been advanced, and the problem is always interesting, but as yet remains unsolved. Many species of birds, of course, do not migrate. Such birds as the crow, quail, cardinal, and woodpecker remain in one region throughout the year, and are called *permanent residents*. Some birds spend only a day or two with us as they pass from north to south or south to north, and are called *transient visitants*. Others come from the north in the fall, stay with us during the winter, and return to their more northern homes in the spring. These are called *winter residents*. Still others come to us from the south in the spring, rear their young in the summer, and return to the south in the fall. These are called *summer residents*.

THE RANGE OF THE GOLDEN PLOVER

Courtesy Spencer Lens Co.

From the Arctic wastes to the tropical areas of South America the golden plover finds its way.

In these days of aërial transportation we read much about intrepid airmen establishing new records for speed, endurance, altitude, and what not. Let us glance for a moment at another type of aërial travel, the records of which are not widely known.

The champion long-distance flier—the Arctic tern. The Arctic tern lives in more hours of daylight and sunlight than any other animal in the world. It nests during the Arctic summer as far north as it can find anything stable on which to construct a nest. When the young are fully grown they leave the Arctic and travel eleven thousand miles to the Antarctic realm at the other end of the world. They travel an average distance of about one hundred fifty miles a day, completing the flight in about ten weeks—a remarkable record, considering the fact that they make many stops to pick up food along the way. When the summer season in the Antarctic begins to wane, the birds start northward again, reaching the Arctic in time for the nesting season.

The champion nonstop flier. The longest continuous flight record is held by the golden plover, which nests along the Arctic coast of North America. As soon as the young are old enough to care for themselves, they fly to the coast of Labrador, where they take on fuel by eating large quantities of native fruits. Later they make a short trip across the Gulf of St. Lawrence to Nova Scotia. From here they take off on a nonstop flight of twenty-four hundred miles southward over the Atlantic Ocean to the north coast of South America—a championship record—and then on south of the Tropic of Capricorn.

BIRDS AS FRIENDS OF MAN

Although some birds are destructive, most of them befriend us by eating harmful organisms. In general, from the standpoint of their service to man, birds may be considered in five groups: *first,* and most important, those that destroy harmful insects; *second,* those that eat weed seeds; *third,* those that destroy small rodents, such as mice and rats; *fourth,* those that eat dead and decayed plant and animal matter; and *fifth,* those that serve as game.

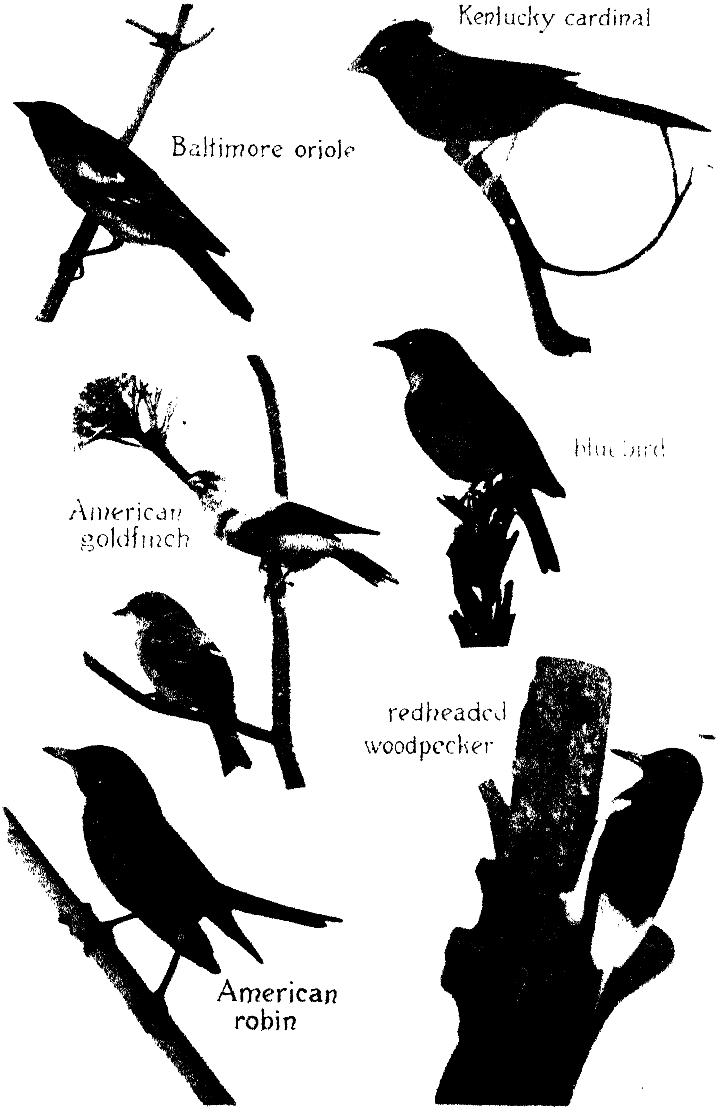
The various states have different laws regulating the hunting of birds. For the most part, only destructive birds or those that have become too numerous may be killed. A true sportsman confines his hunting to birds of these kinds.

This table shows what a few of the most common birds eat.

FOODS EATEN BY BIRDS

NAME OF BIRD	INSECTS	VEGETABLE MATTER	MISCELLANEOUS	"STOLEN SWEETS"
American goldfinch	Cankerworms, plant lice, beetles	Weed seeds	....	Lettuce seeds
Baltimore oriole	Cankerworms, tussock moths, grasshoppers	Wild fruits	....	Green peas
Bluebird	Grasshoppers, beetles	Wild berry seeds	....	A few cultivated fruits
Blue jay.....	Harmful insects	Acorns, nuts	Mice, fish	Eggs and young of other birds
Cardinal.....	Many harmful insects	Seeds, berries	....	....
Catbird......	Insects, especially cutworms and cicadas	....	....	Many fruits
Chickadee....	Beetles, ants, bugs	Weed seeds, pine seeds	....	....
Crow........	Beetles, grasshoppers	Wild fruits	Mice, frogs	Corn, birds' eggs
Cuckoo......	Insects, especially hairy caterpillars	....	....	....
Flicker.......	Ants, bugs	Wild fruits	....	....
Grackle......	Insects	Weed seeds, wild fruits	Mice, snails	Fruits, grains, birds' eggs
Herring gull..	....	....	Dead organic matter	Live fish
Horned owl ..	....	....	Rabbits, rats, mice	....
Hummingbird	Insects	....	....	Nectar
Kingbird.....	Grasshoppers, crickets	A few seeds	A few bees, usually drones	Fruit
Meadow lark.	Beetles, caterpillars	Weed seeds	....	Grains
Nuthatch....	Many harmful insects	Acorns, nuts	....	Fruits
Quail........	Insects	Weed seeds	....	....
Red-headed woodpecker	Insects	Beechnuts, acorns	....	Corn, small fruits
Robin.......	Grasshoppers, caterpillars	Wild fruits	Worms	Cultivated fruits
Sharp-shinned hawk	....	....	Mice	Chickens, other birds
Wren........	Insects	....	....	....

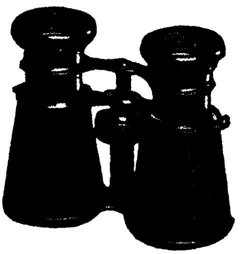
SOME OF OUR NORTH AMERICAN BIRDS



HOW TO STUDY BIRDS

There is not a day in the year when birds are not available for study. Finding them is just a matter of looking and listening. Many birds, however, are suspicious and will not allow us to come near. To study them successfully we should be equipped with a pair of field glasses through which we can watch them at a distance. Then, too, we should have a good bird manual for reference, as well as a notebook for recording our findings.

FIELD GLASSES FOR BIRD STUDY



W. M. Welch Manufacturing Company

Why are field glasses essential for the study of birds in the field? Have you ever used field glasses?

There is considerable satisfaction in making a list of birds by name. True bird study, however, does not consist merely of identification. The greatest benefit comes from observing their habits and noting their life histories. As a guide for such observations, we may think of the following topics.

Outline for Bird Study

1. *Description:* Size, form, colors, and any unusual markings both of the male and of the female birds of various species
2. *Habitat:* Where bird is seen, as woods, field, swamp, along streams
3. *Movements:* Hops, walks, or swims. Flies rapidly or slowly, directly or zigzag; flaps wings continually or soars part of the time
4. *Voice:* (*a*) Song notes—pleasing or harsh, short or continuous; sings on ground, in tree, or in flight; (*b*) call notes—warning, surprise, protest
5. *Food:* Insects, seeds, fruits, rodents, decayed matter
6. *Courtship and mating:* Any interesting traits
7. *Nesting:* Where nest is built, its materials, and construction; color and number of eggs; incubation period
8. *The young:* Period in nest; training by parents
9. *When seen:* Various dates of observations

STORIES OF SOME BIRDS WORTH KNOWING

Small, Insect-eating Birds

The harbinger of spring—the bluebird. The bluebird is usually a favorite in all the northern states, where it is hailed as a forerunner of spring. After spending its winter south of the snow line, it appears about the middle of March with its mate. They proceed at once to choose a site, build a nest, and rear their young. The bluebird is very valuable to man, since much of its food consists of insects. It is also a true American bird, attired in its country's colors—red, white, and blue.

A friendly bird—the robin. John Burroughs, the great naturalist, once paid a tribute to the robin redbreast by calling it "the most native and democratic" of birds. In the North and in some parts of the West, it is clearly a favorite. It seems to be fond of human companionship, for it usually builds its nest near a home. The nest is made principally of grass and mud. The eggs, from four to six in number, are of a beautiful greenish-blue. Two, or even three, broods of young may be raised in a season.

Not only is the robin friendly in the location of its nest, but it is helpful in the selection of its diet, eating mostly insects and worms. Now and then it desires a few cherries and strawberries for its dessert, but it is in no sense a nuisance. Too much stress has been laid on its mischievousness and too little upon the good it does by devouring pests.

The American robin has a wide range, being found all the way from Mexico to the Arctic. Although it usually passes the winter in the southern states and even farther south, it is often a permanent resident in many northern states.

A bird of beauty and song—the cardinal. The name redbird is often applied to the cardinal because of its bright red color. This bird, which is a little smaller than a robin, is loved not only for its beauty but also for its amiable disposition and delightful song. It also is a very valuable bird, since it eats many pests, such as potato beetles, cotton boll weevils, and codling moths. A careful study shows that it does at least fifteen times as much good as harm in its selection of food.

The cardinal is a permanent resident in the eastern half of the United States, where it whistles as cheerfully in winter as in the spring. In other words, it does not migrate, but stays in the same locality throughout the year. It builds a loose-structured nest of bark, twigs, leaves, and grass. The eggs, three to five in number, are of a dull color, spotted with reddish-brown. Usually two broods are raised in a season.

The bird carpenter—the woodpecker. The name carpenter has been given the woodpecker because it continually works on wood. Its activities, however, vary from those of a human carpenter in that it not only chisels out its home in wood but also pecks out its food as well. Using its tail as a prop and clinging tenaciously with its toes, two at the front and two at the back of each foot, it holds to the bark of a tree while it taps. From the bark it takes such food as insect eggs, grubs, beetles, and spiders.

ONE OF THE LARGE WOODPECKERS

Courtesy Spencer Lens Company

This male flicker has just returned to his nesting site in a dead tree.

Of the common woodpeckers, the flicker, which is a little larger than the robin, is the largest. It is so popular that it is known by at least thirty different names, among which are yellow-hammer, high-hole woodpecker, and golden-winged woodpecker. The flicker differs from its cousins not only in color, but somewhat in food habits in that it spends much time on the ground looking for ants. While hunting, it is inconspicuous because of its finely barred coat of brown, which blends with its surroundings.

Another common carpenter is the red-headed woodpecker, noted for its beautiful colors. Its head, neck, and throat are crimson; its underparts white; its back, black and white. Despite its beauty, it is the ruffian of the family, being very noisy and quarrelsome throughout its waking hours.

The yellow-bellied sapsucker is the real "black sheep" of the woodpecker family. It gets this reputation because it drills holes entirely through the bark into the cambium layers of trees, sometimes causing their death. It does this so that insects will come to drink the sap that oozes through the holes and thus become easy prey. The truth of the matter is, the sapsucker catches so many obnoxious insects in this way that we can well afford to overlook any damage it does to the trees.

KILLERS AMONG THE BIRDS

THE UGLY BUZZARD

Ferdinand Hirsh

This picture indicates how ugly a buzzard is in real life. Its habits are just as ugly as its looks, for it feeds almost entirely on filth.

Buzzards, owls, hawks, and eagles are well called Raptores (răp-tō′rēz), from the Latin word *raptor,* meaning "robber," being suitably equipped to capture small animals. Their strong hooked bills enable them to tear flesh. Their toes, three in front and one behind, are provided with strong claws by which they hold their prey. Their powerful wings permit them to carry away many animals, such as rats, mice, rabbits, and fish, which they continually seek as food. They hunt continually, sometimes even at night.

Ugly scavengers—buzzards. Although repulsive in their habits, buzzards really are friends. They do not seem to care for fresh meat, but prefer dead bodies, garbage, and other similar wastes. If disturbed when eating, they resort to the loathsome trick of disgorging the contents of their stomachs.

Birds of the night—owls. Since they eat many small mammals that move about at night, most owls are nocturnal in their habits, doing most of their hunting in the dark. In spite of the fact that farmers often accuse them, especially the

A SNOWY-BEARDED VIKING AND RED-TAILED HAWK

Lynwood M. Chace

Like a viking of old, the snowy owl cruises down the eastern coast of North America.

Lynwood M. Chace

Once a wild duck feels the talons of the red-tailed hawk, escape is impossible.

large barred species, of seizing poultry as prey, they make up their diet largely of mice, rats, lizards, and insects.

The screech owl, one of the smallest members of the family, is probably the most familiar. This little bird is only slightly larger than a robin, but has a rather weird voice that may startle us at night as it calls in the distance. If we listen to it sympathetically, however, we may find its notes rather pleasing and inviting. Barred and barn owls give forth loud hoots and occasional blood-curdling screams, but we may even enjoy listening to them, too, for their notes seem very strange and fascinating.

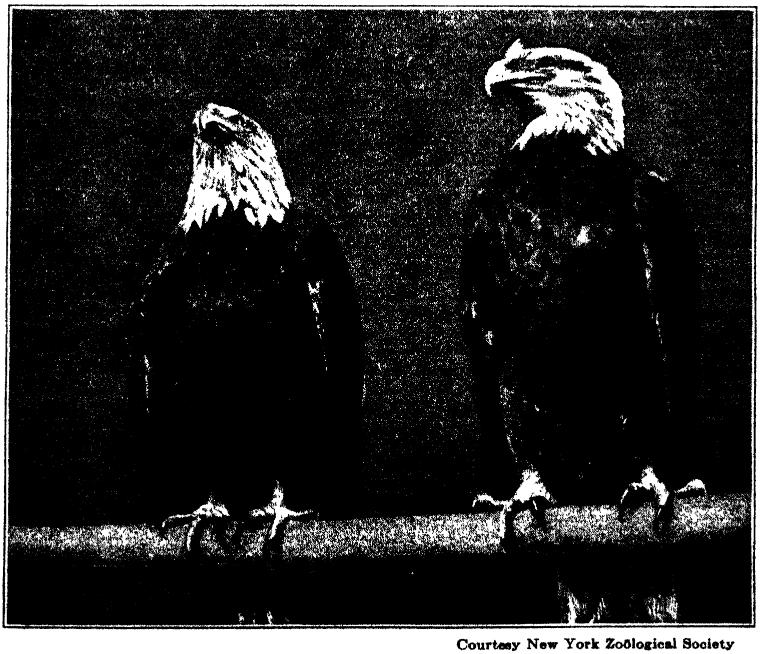
Birds with a bad reputation—hawks. Despite their reputation, some hawks have very good traits. The sparrow hawk, for instance, might be considered a friend except for its occasional attacks on song birds. This much may be said in its defense, that it will not carry on these attacks so long as insects and mice are available. The red-shouldered hawk and the red-tailed hawk are both important allies in the war against insects and rodents. unfortunately, however, both these

birds make frequent raids upon poultry and are sometimes called hen hawks because of their great destructive tendency. The marsh hawk is generally regarded as a friend. Unlike its cousins already mentioned, it flies low along the ground to catch insects, field mice, and other pests.

The sharp-shinned hawk and the Cooper's hawk are more harmful than all the other hawks together. These hungry birds of prey will swoop down out of the sky and sink their talons into chickens even if the owner is standing near. Because they can fly fast, dodging and darting as they go, they are also dangerous enemies of birds in flight.

The majestic eagles. It is not surprising that one of the eagles, the *bald* eagle, has been chosen as the emblem of our country. This eagle is one of the largest birds in America.

OUR NATIONAL BIRD—THE BALD EAGLE



Courtesy New York Zoölogical Society

Notice how stately these birds appear. We can readily understand, when we consider ı of the bald eagle, why it has been chosen as our national bird.

The male averages thirty to thirty-three inches in length, and the female thirty-five to forty inches. It is noted for its majesty of appearance, its wonderful power of flight, its keen sense of vision, and the devoted care which it gives its family. During the first ten weeks of its life its down changes from white to gray; within three months it grows a coat of dark brown feathers; and during the third year it develops a white bald head and white tail.

Eagles have become so rare that in many parts of the country, when one is seen, local papers feature the news. They are common, however, along the shores of Lake Superior.

CONSERVATION OF BIRD LIFE

Birds mean much in the life of man. Their value is threefold: economic, scientific, and aesthetic. Because of their great value, we should do all we can to conserve their lives. We can help, especially in the winter, by providing birdbaths, feeding boards, and birdhouses. Once having attracted the birds in this way, we must of course make every effort to protect them from such enemies as cats, dogs, and even small boys who do

AN EVIDENCE OF FRIENDSHIP

Ewing Galloway

Birds are easily attracted by a feeding board such as that shown above. A feeding board placed in a back yard will help many birds and bring much pleasure to the owner.

not appreciate their worth. Then, too, we should try to protect them from quarrelsome enemies among other birds.

It is exceedingly important that adequate legislation be maintained to safeguard our feathered friends. We need more bird sanctuaries and reservations. With these thoughts in mind, we should be constantly on the alert to emphasize the need of bird conservation.

Problem 3. What are the haunts and habits of fur-bearers?

From earliest times hunting, fishing, and trapping have been fundamental ways of making a living. The early history of our own country is closely wrapped up with these activities, particularly trapping. The picturesque and romantic stories of brave and hardy trappers reveal an important phase of early American life. In recent years, however, because of the scarcity of wild animals, trapping as an occupation in the United States has greatly declined and in some regions has nearly disappeared. In fact, at the present time it is limited only to certain animals designated by law in the various states. These laws limit the seasons for hunting, the size and number of the catch, and the kind of equipment that may be used. The aim, of course, is to conserve life and prevent the complete destruction of certain forms. It is being recognized that many of the fur-bearers are our friends and should be protected.

The wild animal's bill of rights. The question as to which animals should be protected and which ones should not, as well as how much protection should be afforded, presents a real problem in present-day living. In this connection the statement of Hornaday, a famous authority on wild life, gives us rich food for thought. He says, "Toward wild life, our highest duty is to be sane and sensible, in order to be just, and to promote the greatest good for the greatest number. Be neither like a Hindu fanatic of the castes nor a cruel game-butcher like a certain wild animal slaughterer whom I knew, who while he was on earth earned for himself a place in the

hottest corner of the hereafter and quickly passed on to occupy it."[1]

Hornaday's interest in the problem of conservation is further shown in a platform which he has proposed as a guide for our relations with wild animal life. This platform is composed of twenty-six articles, which he labels "The Wild Animal's Bill of Rights." Three articles which have a direct bearing on the subject of trapping follow:

ATTRACTIVE INHABITANT OF THE WOODS—THE DEER

Courtesy Department of Interior, Canada

Few animals have greater beauty than a deer. It is very shy, however, and seldom can be observed at close range.

Article 3. Under certain conditions it is justifiable for man to kill a limited number of the so-called game animals on the same basis of justification that domestic animals and fowls may be killed for food.

Article 4. While trapping of fur-bearing animals is a necessary evil, that evil must be minimized by reducing the suffering of trapped animals to the lowest possible point, and by preventing wasteful trapping. [This article is extremely important.]

Article 7. The extermination of a harmless wild-animal species is a crime; but the regulated destruction of wild-animal pests that have been proved guilty is sometimes necessary and quite justifiable.

[1]Quoted from *The Minds and Manners of Wild Animals*, by permission of William T. Hornaday, author, and Charles Scribners' Sons, publishers.

Minimizing cruelty to animals. In harmony with the foregoing articles, it is now commonly agreed that a certain amount of hunting and trapping may be carried on under such regulations as will insure the continuance of desirable forms of life. Certain animals are dangerous and destructive and must be killed off because of the damage they do. Others tend to become too numerous, and would become destructive if their numbers were not continually reduced by hunting. Then, too, most fur-bearing animals have great economic value for fur and sometimes as food. Sportsmen favor the protection of animals under these principles and are opposed to the needless destruction of life. More and more they are actively supporting the cause of conservation.

A TRAPPER SETTING HIS TRAP

Courtesy W. A. Gibbs & Son, Inc.

The trapper hopes to catch a muskrat. One of the best places to trap a muskrat is along the bank of a stream

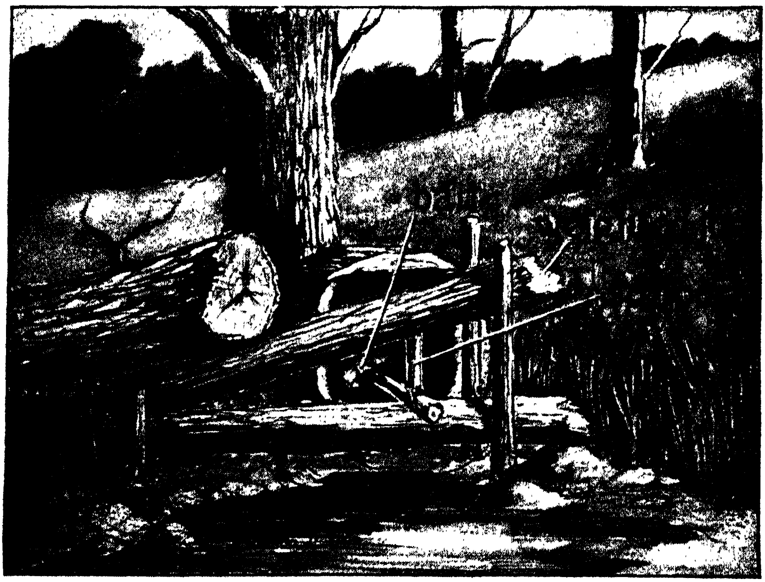
METHODS OF TRAPPING

Long before the white men came to America the Indians were expert trappers. Among all their traps one of the most unusual was used by the Cherokees. This trap, intended primarily for wolves, consisted of a sharp knife imbedded in a bait of frozen fat. An animal would come up to the trap,

lick the frozen fat, and cut its tongue so that it would bleed profusely. The blood would attract other wolves and cause a free-for-all fight. In this fight some of the wolves would be killed, and the Indians would secure many hides.

Trapping becoming more humane. Within recent years trappers have tried more and more to use methods that cause captured animals as little suffering as possible. Traps may be divided into three general classes: first, *inclosing* traps, those which confine the victim without injury; second, *killing* traps, those which crush or cut the victim to death; third, *arresting* traps, those which seize the victim without killing unless it is caught by the neck. The inclosing traps include *pitfalls* and *door traps*. Pitfalls are of two general kinds, those dug in the earth and those that hurl an animal into a box. The door traps range in size from the great cages that are used for catching tigers and other large beasts down to the common

AN OLD-STYLE TRAP—THE DEADFALL



This crude trap was used by the American Indians. When an animal pulled at the bait, the support was loosened and the log fell, crushing the victim or holding it tight.

SETTING A "LIVE" TRAP

Courtesy W. A. Gibbs & Son, Inc.

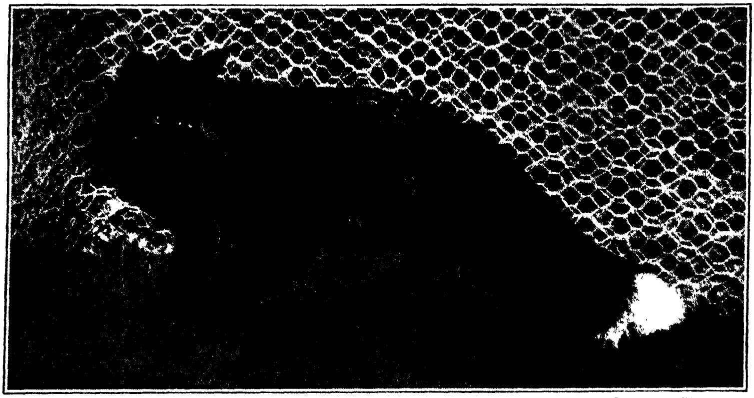
This trap, which is classed as an arresting trap, captures an animal alive and raises it out of the water. Thus it keeps the animal from suffering the effects of drowning.

box traps used for catching mice, rats, and rabbits. The killing traps include *noose traps* and *deadfalls*. Although these were formerly quite widely used, especially by the American Indians, they are seldom used today. Arresting traps are usually steel traps that operate by the release of a spring. The following table describes some of these traps and indicates the animals for which they are best adapted.

STEEL TRAPS

SIZE	DESCRIPTION	ANIMALS
One.....	4-inch spread, single spring	Muskrat, weasel, opossum, mink, marten
Two.....	4⅞-inch spread, light, durable springs	Fox, skunk, raccoon
Three...	5½-inch spread, strong double springs	Otter, badger, coyote, wildcat, lynx

A FUR PRODUCER—A FOX



Century Photos

Before long the fur on this animal will help to keep somebody warm.

Advantages of fur farming. Within recent years a movement has started to raise various kinds of fur-bearing animals, particularly the fox, upon special farms or large ranges. It has been found that many fur-bearing animals can either be domesticated or kept in a half-wild state in this manner. The movement to raise fur-bearing animals is being encouraged for three good reasons: first, all methods of trapping cause more or less suffering; second, many fur-bearing animals are rapidly being exterminated; and third, these animals may be raised on land that would otherwise be unproductive, such as rocky land that is unfit for farming and land in hilly and barren mountainous regions.

HAUNTS AND HABITS OF SOME FUR-BEARERS

The most important fur animal—the muskrat. Of all the fur-bearing animals, the muskrat is the most important, not for the value of a single pelt, but for the great number of pelts the species furnishes. Although such animals as the beaver, otter, marten, seal, and many others have been practically exterminated in certain parts of the country, the muskrat lives on. This happens for two reasons: (1) it raises two or three litters of young a year, each litter ranging in number

A MUSKRAT AT WORK

Dr. R. W. Shufeldt

How does the muskrat's mode of life enable it to escape extinction?

from three to thirteen; (2) it has aquatic habits and thus escapes many dangers. The muskrat is found in nearly all parts of North America. Its home is generally located in marshland, in the widened part of a river, or at the end of a lake. The oval chamber of the house is located above the water, but the entrances are usually under the water. This arrangement permits the muskrat to come and go without being seen.

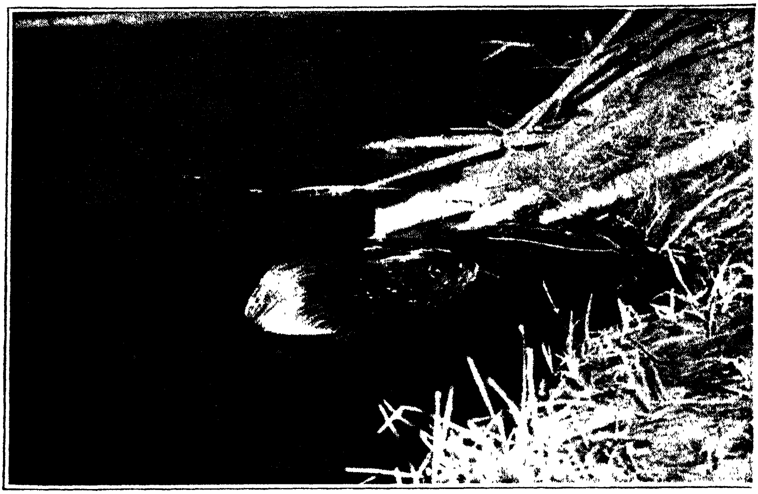
The average length of a muskrat is about twenty-one inches and it weighs approximately four pounds. Its diet consists principally of the roots and stems of water plants, fresh-water clams, and occasionally the eggs and young of marsh-nesting birds. It is largely nocturnal in its habits.

MUSKRAT TRACKS

Note the trail made by the tail.

The wild-animal engineer — the beaver. One of the most interesting of the fur-bearers is the beaver, a small animal that weighs from thirty to fifty pounds and attains a length of about three and one-half feet. As an architect or builder the beaver is a master. One noted authority on wild life says that its thoughtful planning, its reasoning power, and its mechanical skill in constructive work and its unusually great industry are unexcelled except by man.

A FAMOUS ARTISAN



Courtesy *Nature Magazine*

This picture shows a beaver swimming in a small stream. The upper right-hand corner of the picture shows part of a beaver dam that extends across the stream. Notice how the pieces of timber are placed to offset the strength of the current.

The beaver at home. Since the beaver is very shy and wary, it never builds its home in the open. Instead it selects a secluded spot along a small, shallow stream. It seems to realize that a home along a small stream will be safer than a home along a larger one. If possible, it chooses a stream lined with birches, poplars, and alders.

The first thing that the beaver does in its building program is to construct a dam across a stream. It builds the dam to hold back the water and to make a pond. First of all, it begins to cut down trees from which to secure materials. To fell a tree, it gnaws round and round the trunk, about a foot or two above the ground. It keeps gnawing in this way until the trunk becomes weakened and the tree topples over. When the tree is on the ground, the beaver cuts the limbs and sometimes the trunk into short pieces and floats them into place in the dam. It places the pieces lengthwise with the current in a semicircular arrangement. This helps deflect the water and keeps it from striking against the center of

the dam with full force. To hold the pieces of timber in place, the beaver weights them down with earth and stones.

The dam backs up the water and causes the stream to overflow the adjoining low land. Then the beaver begins to build its home. Like the muskrat, it builds the entrance below the surface of the water, but the lodge itself above the surface. It makes the lodge rather large, usually six or seven feet in diameter. It repairs the lodge every year, likewise the dam. In building its lodge it works with the members of its family, but in building a dam it works with all the members of the colony.

Trapping the beaver. Because of its keen senses the beaver is a difficult animal to trap. It can detect the presence of an enemy by even the slightest traces. Its sense of smell, for instance, is so strong that a trapper must thoroughly wash his hands before he handles and baits his trap. Despite the vigilance of this wise animal, however, its numbers have been greatly reduced. The fact that it lives in communities and builds dams has made it an easy animal to locate. Furthermore, it is a very valuable animal because of its fine pelt.

A SLY LITTLE CREATURE
A YOUNG FOX

Lynwood M. Chace

This little creature seems very shy, but, as a matter of fact, it is really very sly. If we watch it carefully, we can foretell many of the characteristics that it will reveal later.

Reynard the fox. Ever since the time of the ancient Greeks the fox has held a prominent place in literature. Everybody is familiar with such common

expressions as "foxy" or "sly as a fox," which indicate something of its behavior. Although it is extremely versatile, it is best known, perhaps, for its cunning ways of eluding its pursuers. When it is being chased, it doubles back on its tracks to elude its pursuers. If it comes to a fence, it may hop upon it and run along the top to make the dogs lose its scent. If it comes to a stream, it may jump into the water and swim away. If it comes to a leaning tree, it may run up the trunk and jump from branch to branch. In the winter it often skims over thin ice, causing the pursuing dogs to break through and later to give up the chase. Even though it manifests all this cunning, it becomes greatly confused and almost senseless when it finds itself really hard pressed by an enemy.

FOX TRACKS

The fox really is not so bad as it has been portrayed. Although it is guilty of eating chickens and ducks and is fond of ground birds and their eggs, it more than pays for its misdeeds by consuming rats, mice, and other harmful rodents. It usually builds its home or den under rocks, old trees, or in a natural hole in the earth. Then, just as we might expect, it prepares several entrances to its den. It is hunted for its thick pelt, which is extremely valuable.

The destructive weasel. In proportion to its size the weasel is extremely vicious and fearless. The male is only sixteen inches long, and the female only thirteen, including a tail of five inches. The weasel is very active, racing along the ground and through the trees as lively as a squirrel. In spite of its small size, however, it attacks almost anything in its path. Sometimes it even attacks horses and cows. It hunts both under the ground and on the surface, making its meals largely of rabbits, squirrels, rats, mice, birds, and chickens. Often it kills more of these animals than it can eat, and satisfies itself by sucking the blood and eating the brains. Strangely, in the northern states it changes its color with the seasons. During the summer it is light brown,

but in winter it is pure white, except for the tip of its tail, which is jet black. Its white color enables it to move about very stealthily when the ground is covered with snow.

The "wolf" of the prairie — the coyote. The coyote is often spoken of as a prairie wolf, but it is really not a wolf. It has the same general appearance and craftiness of a wolf, but it is much smaller and far less courageous. For a home, it digs a burrow in the ground. Here it hides and rears its young, sometimes as many as fourteen in a single litter.

The coyote, like the wolf, hunts in packs and is most active at night. Its prey consists chiefly of prairie dogs, gophers, jack rabbits, and sage hens. It also frequently kills sheep and sometimes young calves. Since it is so destructive, a relentless war has been waged against it and its numbers are decreasing. Even so, if we were to travel the prairies we should still hear its howl.

A SMALL VICIOUS ANIMAL
THE WEASEL

Century Photos

In the North, where there is considerable snow in winter, the weasel changes its brown summer coat to white. In the South, where there is little or no snow in winter, it keeps its brown coat all the year round.

A PRAIRIE HOWLER—THE COYOTE

Have you ever seen a coyote? Have you ever heard it howl? Just how does it differ from a wolf?

Bruin and his relatives — the bears. Bears are found on all the continents except Australia. From ancient times down to the present, they have occupied a very prominent place in literature. They have been popular because of their many interesting and human-like qualities. At a circus or zoo they always attract a great deal of attention. Although they are sometimes considered ferocious, they are not so dangerous as many people imagine. As a matter of fact, they are usually good-natured, and seldom attack human beings. On the other hand, just as we are occasionally as "cross as a bear," they, too, have their off moments. Even when they are in a fighting mood, however, they are not so mean as a wolf or so treacherous as a tiger or a lion.

BEAR TRACKS

Bears are large animals, with long shaggy hair, small ears, and very short tails. Although they are clumsy in appearance, they are really nimble and active, being good runners, climbers, and swimmers. Their tracks somewhat resemble those of a man, the entire bottoms of the feet touching the ground when they walk. Although they belong to the order of flesh-eating animals, they eat mostly vegetables and fruits. Among the animals which they eat are such prey as large black ants, grubs, frogs, snails, fish, seals, and walruses.

Black bears the best known. Of all the bears, black bears are the most common. Their name, however, is misleading, as they may be brown, cinnamon, or even yellowish, in color. They average about five feet in length, sometimes weighing as

BLACK BEARS IN FLORIDA

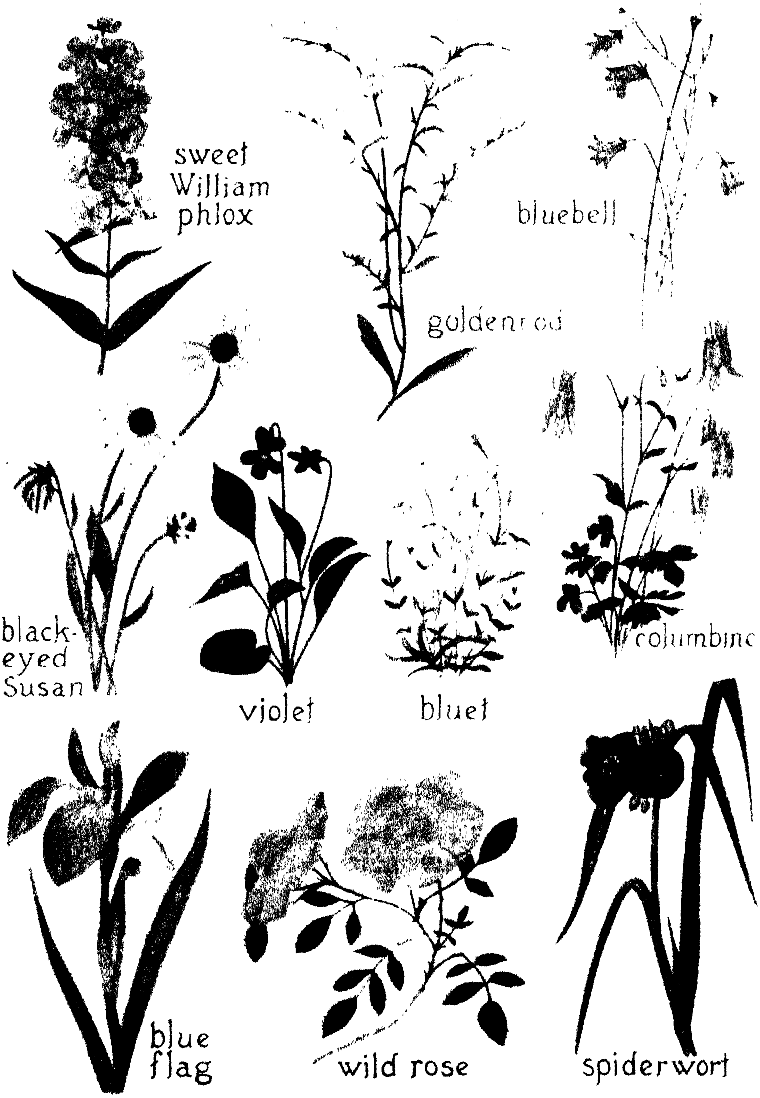
Courtesy Field Museum of Natural History

Although most people prefer to become acquainted with bears in a circus or zoo, they have little to fear in meeting them in their own habitat. Bears usually are dangerous only when they are wounded or are aroused in defense of their young.

much as four hundred pounds. In winter they hibernate in large hollow trees, caves, or dens of their own digging. In the North, the period of hibernation may last four months of the year. It is rather difficult to understand how animals of their size can go so long without food, but they seem little the worse for their long sleep. The chief effect is that they lose considerable weight and consequently acquire a ravenous appetite. Within a few weeks, however, they regain their weight and look very plump. Black bears are killed for their hides, but their hides are less valuable than those of the wolf and fox. Despite unlimited killing, black bears are found here and there all the way from Maine to Mexico.

Other important fur-bearers. Space does not permit discussion of the many other fur-bearing animals found in various parts of our country. Among those which we should find very interesting are the opossum, mole, raccoon, skunk, otter, marten, and badger. Some of these animals are still quite common, but others are rapidly disappearing. The references at the end of the unit suggest various topics that we may read in order to learn about their special haunts and habits.

SOME AMERICAN WILD FLOWERS



Which of these wild flowers have you observed in their natural habitats? Which grow in damp shady places? Which grow in the sunlight? Which do you like best?

Problem 4. What are some of the wonders of wild-flower land?

Just as birds, fish, and fur-bearers have interesting life stories, so have the inhabitants of wild-flower land. To enjoy thoroughly our walks, hikes, and drives through the country, we should learn as much about these inhabitants as we can.

PROTECTING THE BEAUTY OF NATURE'S TRAILS

Unfortunately, many people have never learned to appreciate the wonders of wild-flower land. They carelessly pick and destroy flowers, even the rarest and most delicate ones, as if these flowers have no value at all. In fact, this has happened so often in certain localities that many valuable flowers have nearly disappeared. If we but think of the world without flowers, we can appreciate how necessary it is that we protect them just as we do other valuable forms of life. True it is that many flowers which brighten our roadsides, fields, and forests offer strong temptations. Such flowers as wild roses, dogwood, wild crab apple, azalea, holly, American redbud, and mountain laurel, however, should never be gathered, no matter how common they are, except for purposes of study. It should not be necessary to have laws to prohibit the gathering of rare plants. We should appreciate their beauty and interesting history sufficiently to permit them to adorn our landscapes unmolested. One authority on wild flowers properly says, "A wild flower looks most beautiful where it grows."

HOW TO STUDY WILD FLOWERS

The study of wild flowers is very fascinating. It includes a number of interesting activities. The following list mentions some of the activities that we may wish to carry on as we proceed with our work:

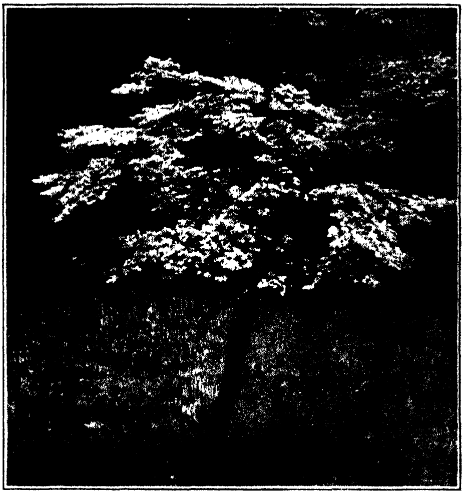
1. Photographing wild flowers in their natural settings
2. Preparing wild-flower calendars
3. Cultivating wild-flower gardens
4. Preparing mounted collections of wild flowers

MORE AMERICAN WILD FLOWERS

Which of these wild flowers have you observed in their natural habitats? Which grow in damp shady places? Which grow in the sunlight? Which do you like best?

Photographing wild flowers. One of the most valuable instruments in the study of wild flowers is the camera. It is valuable because it enables a student to investigate without destroying life. Moreover, the photograph of a flower shows its natural condition and its natural environment. A pressed specimen, on the other hand, looks dead and uninteresting.

A DOGWOOD IN BLOOM



Orville Logan Snyder

Certainly nobody would want to break off the branches of a tree such as this. Even a careless observer will respect its great beauty.

Whenever a student uses a camera, he should be careful to use it correctly. He should take each picture from the most effective distance and angle, and should try to overcome the effects of shadows. If possible, he should take two or three photographs of each flower, varying both the distance and angle. Then one picture will help to support another in supplying detailed information.

Preparing wild-flower calendars. One of the most interesting ways of studying nature is to make a record of observations, such as a wild-flower calendar. This record should include (1) the place where the flower is observed, as county, township, or farm; (2) the nature of its habitat, as open woods, field, roadside; (3) the date when it bursts into bloom; (4) other notes of special interest; and (5) the date of observation. Also, the flowers may be grouped according to the months in which they appear, such as March and April. Such a study suggests a hobby that may last through many years.

Cultivating wild-flower gardens. One of the most interesting things we can do in the study of wild flowers is to plant some

of them about our homes. First of all, of course, we must provide a favorable habitat. We may do this by getting rich soil from the woods, thus providing conditions as much like those in the woods as possible. When we dig up the flowers we should be very careful to leave considerable soil clinging to the roots, for most species die quickly when their roots are exposed to the air. The garden will be much more interesting if we select plants that bloom at different times of the year.

Preparing mounted collections of wild flowers. Sometimes when people study wild flowers they press and dry different specimens and mount them on sheets of stiff paper. A collection of sheets of this kind is known as a *herbarium.* Making a herbarium is an enjoyable project and is also an excellent way in which to study flowers, provided we are careful not to destroy valuable plants.

In picking a specimen for a herbarium we should aim to get a good representation of the plant with its flower or fruit, part of the stem and leaves, and if possible the root. The plant should then be placed between folded sheets of a newspaper with blotters over it to absorb the moisture. A number of folders that contain specimens may be placed in a pile, provided pieces of corrugated cardboard are placed between them so that the moisture can evaporate. A board should be placed on top of the pile, and on the board a weight of from fifty to one hundred pounds. Care must be exercised in using the weight. If it is too light, the specimens will have a tendency to wrinkle, and if it is too heavy, fleshy plants will be crushed. When the blotters become moist, they should be replaced by dry ones, thus shortening the drying process and making it possible for the color of the flowers to be retained.

When a plant is thoroughly dry, it should be glued or fastened by means of tape to one of the sheets of the herbarium. At the lower right-hand corner should be written (1) the name of the plant, (2) when and where collected, (3) the nature of the habitat, whether wet or dry, sunny or shaded, etc., and (4) any other information that may be useful or desirable.

FLOWERS TO LOOK FOR ALONG THE TRAILS

It is impossible to suggest in a limited space the means of identifying all the wild flowers that we should learn to know. The references at the end of the unit will suggest how to study several of the more important species. The discussions on the following pages merely cover the types that may be found in different sorts of habitats.

A sure sign of spring — the spring beauty. In early spring moist open woods are often carpeted with the lovely flowers of the spring beauty. These flowers may be identified by their five petals with rose-colored veins and their long, narrow leaves. They are most common in the country, but they are often found within the limits of cities in the parks and along the boulevards. They like an abundance of light, and when the day is cloudy the flowers close up as if wilted. Spring beauties have a wide range, being common from Maine to all our southern states.

A LADY'S-SLIPPER

Hugh Spencer

This lady's-slipper is a member of the orchid family. It is often considered one of the most beautiful wild flowers to be found in the woods.

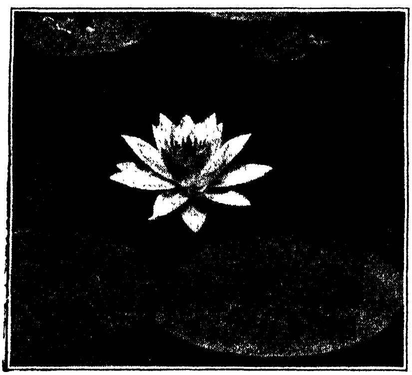
The yellow lady's-slipper. The yellow lady's-slipper, which is an important member of the orchid family, is sometimes called the yellow moccasin. It has a slender leafy stem ranging from twelve to twenty-four inches in height. Its flower has a large, golden-yellow, slipper-like pouch topped by two narrow petals, back of which are two long, narrow, greenish-yellow sepals. The pouch or moccasin serves as a banquet hall for bees. Here

they carry nectar and pick up pollen, which they spread to other flowers as they fly about. The yellow lady's-slipper blooms from May to July in bogs, thickets, and moist, hilly woods.

Jack-in-the-pulpit. As a rule the Jack-in-the-pulpit lives in a shaded, wet woods. Its flowers are clustered on a clublike structure called the *spadix* (spā′dĭks), set in a cup over which hangs a hood like the canopy of a pulpit. The spadix is often referred to as Jack and the cup and hood as his pulpit. The fruit is borne on the spadix. Years ago the Indians discovered that the Jack-in-the-pulpit when cooked made a tasty, nutritious food. This accounts for the fact that the plant is often called the Indian turnip.

Queen of the water—the water lily. Because of its exquisite beauty the water lily is often called the "queen of the water." It includes several species with a variety of colors—white, pink, blue, or yellow. One of the most common is the pond lily, which grows in quiet shallow water. It has broad, leathery leaves that float on the surface of the water and creamy-white flowers, often five inches in diameter when fully developed, that rise above the surface. These flowers are very short-lived, lasting only two or three days. The blossoms usually open in the morning and close in the afternoon. Another flower sometimes found in the same pond with the pond lily is the common odorless yellow pond lily, or "spatterdock."

A WATER LILY



Ferdinand Hirsh

This is but one of the many varieties of water lilies that deck the surfaces of ponds.

A stately wild flower—the iris. The wild iris grows in swamps and in the wet margins of ponds. It has a beautiful form and color and is considered one of the most stately wild flowers to be found. In fact, one form of iris, the fleur-de-lis,

because of its stately appearance, has been selected as the national flower of France. The wild iris has a stem one to three feet high, bearing long, flat, slender leaves. It has large violet-blue flowers, variegated with green, yellow, or white.

Other interesting flowers. The foregoing, of course, covers only a few of the flowers that we wish to study. As we explore the fields and woods, we shall find many other interesting species. Among the most interesting are the following: wood anemone, trailing arbutus, bloodroot, May apple, Dutchman's-breeches, trillium, violet, wood sorrel, adder's-tongue, forget-me-not, prickly pear, common buttercup, wild columbine, pitcher plant, water arum, and wild pink.

Problem 5. Why and how should we become acquainted with our trees?

Trees are sometimes called "the kindly old giants of the plant world." We respect them more than other forms of plant life because they are the oldest and largest living things and are exceedingly useful to mankind. Without their presence the landscape would be drab indeed.

A SLOPE IN NEED OF TREES

Courtesy U. S. Forest Service

Had this slope been covered with trees, it would not have been cut by the great gulleys shown in the picture.

How trees help us. Forests that formerly covered much of our land had a greater part in the success of our country than we ordinarily realize. From the trees of these forests our forefathers built their simple homes, secured their fuel, and made their tools. The accumulation of fallen leaves and decayed timbers from these forests added so much

A SCENE NEAR A LUMBER MILL

Courtesy U. S. Forest Service

We see so many things around us made of lumber that we fail to appreciate how much lumber means to us. What would happen, though, if we had no lumber to use?

fertility to the soils that we have become one of the most prosperous agricultural countries of the world. Then, too, these forests have enabled us to build up a great lumber industry that has furnished the raw materials for the manufacture of thousands of wood products.

Trees conserve the soil; that is, they keep it from washing away during and after heavy rains. The soil is held back by roots and by the decaying leaves and other vegetable matter that cover the surface of the ground. Thus the soil and its surface coating absorb the water so that it flows off slowly, lessening the chances of floods. This explains the fact that woodland streams, and sometimes woodland springs, continue to flow during a dry season long after those in the open country have completely dried up.

Trees also are valuable in that they are the friends of many plants and animals. Without them many of the choicest wild

flowers and ferns would have no sheltering canopy. Thus they add to the beauty of the world not only by what they are themselves but by the many tender forms of vegetation they protect. Then, finally, birds, squirrels, and many other wild folk are dependent on trees for some of their choicest homes. Indeed, if it were not for trees, the world would be a very dreary place.

The two large divisions of trees. Trees are referred to as (1) *evergreen* or *coniferous* and (2) *deciduous* or *broad-leaved* trees. Some of the most important conifers are the pine, larch, fir, hemlock, spruce, white cedar, juniper or red cedar, rare and local sequoia, and bald cypress. Among the representatives of the broad-leaved families are the magnolia, linden, horse-chestnut, maple, rose, olive, elm, mulberry, sycamore, walnut, birch, oak, beech, and willow.

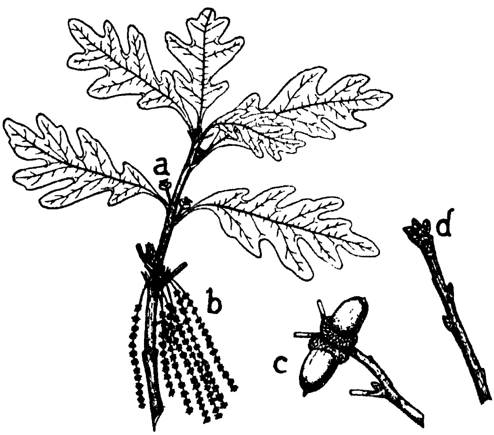
Where to study trees. If we live in the city, we may have very little opportunity to study trees, but we can always find a few around our home or school, along the streets, or in the parks. If we live in the country, on the other hand, we may have many trees in our environment and may know how they grow in natural habitats. In many communities trees are cultivated in aboretums, in forest preserves, and on private estates. Some of these trees are rare and have exceedingly interesting stories. Camping in summer affords an excellent opportunity to study native trees. It is not uncommon to find twenty-five or more native species in some localities. To learn the names and characteristics of these trees is an interesting and profitable way of spending our leisure time.

How to study trees. The first thing we usually want to know about a tree is its name. Each tree has two kinds of names—a common name and a scientific one, which is much more difficult. For example, the common name of one of our best-known trees is *white oak*, and its scientific name is *Quercus alba.* A tree may have several common names, but never more than one scientific name.

The next step in the identification of trees is the study of their general characteristics, such as height, color, and shape.

Then, as we become more intimately acquainted with them, we should study their bark, buds, leaves, flowers, and fruits. Also, we should study their habitats, whether they live on high ground or in low swampy places, whether in open fields or in thickly wooded sections. We can see that, if we are to know trees well, we must observe them throughout the year. This is especially true of trees that shed their leaves in winter. They present a different appearance every season of the year.

LEAVES, FRUITS, AND FLOWERS OF THE WHITE OAK



This drawing shows the following parts:
a. Pistillate or female flower
b. Staminate or male flower
c. Fruit or acorn
d. Winter bud

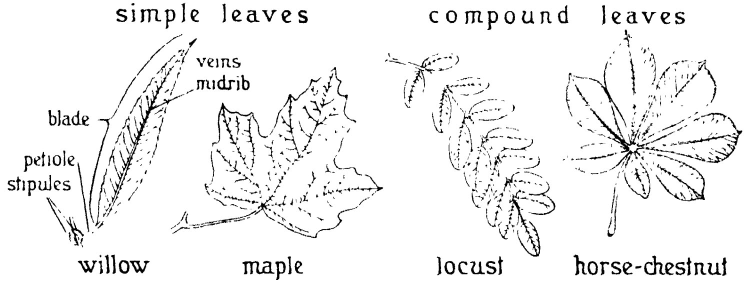
Trees in the spring. The leaves of most deciduous trees are so showy and we are so glad to see them in the springtime that we are likely to overlook the fact that trees also bear flowers. In March, however, the tiny red blossoms of the red maple appear, and from then on to June, willows, alders, birches, oaks, wild crab apples, hawthorns, honey locusts, tulip trees, and many others in turn bedeck themselves in their finest regalia.

Summertime, the leafy season. Summer is the time to study foliage, for then the leaves have reached their mature size and color. When leaves first burst from their protective winter coverings, they are very small. Then, too, they are pink, red, white, gray, or yellow according to the variety of tree. After a few days in the warm sunshine they take on their characteristic shade of green.

Only two kinds of leaves. In general, there are only two kinds of leaves, *simple* and *compound.* A typical simple leaf,

such as that of the willow, consists of the *blade*, or broad part; the *petiole*, or stalk; and sometimes two *stipules*, or appendages attached to the twig at the base of the petiole. A typical compound leaf, such as that of the locust, consists of a petiole and two or more separate parts called *leaflets*. These leaflets are sometimes mistaken for leaves.

TYPES OF LEAVES



Notice the difference between simple leaves and compound leaves. Also notice the difference in the veins of the leaves. Which leaves are parallel-veined? Which one is netted-veined? Which three are pinnately veined? Which one is palmately veined?

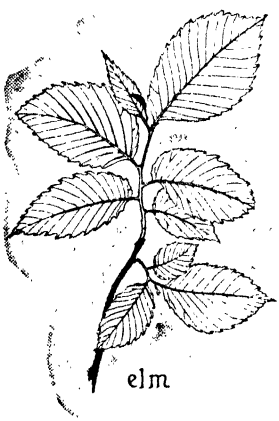
Vein patterns in leaves. All leaves have veins. The way they are arranged is called *venation*. In some leaves several main veins run side by side from the base to the tip of the blade. Such leaves are said to be *parallel-veined*. In other leaves the one main vein (*midrib*) or main veins branch many times and are said to be *netted-veined*. Leaves like those of the elm, which have strong veins extending out from the midrib like the barbs on a feather, are said to be *pinnately veined*. Leaves like those of the maple, in which the veins extend from the end of the petiole like the fingers from the palm of the hand, are said to be *palmately veined*. Only monocotyledonous plants, such as grasses and lilies, have leaves with parallel veins. Since most deciduous trees native to the United States are dicotyledonous plants, in our study of trees we shall be concerned chiefly with leaves that have netted veins.

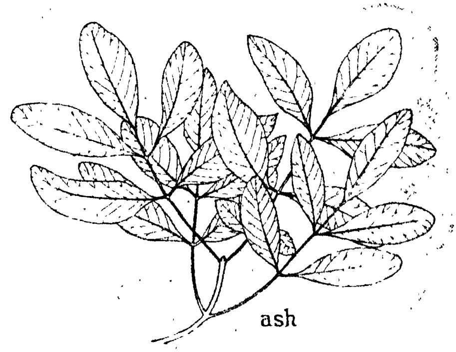
Margins of leaves. Some leaf blades have smooth margins and others have lobed or indented margins. The margins always follow the venation. Most of the oaks, for example,

have simple *pinnately lobed* leaves, and most of the maples have simple *palmately lobed* leaves. In the case of compound leaves the indentions extend entirely to the midrib dividing the blade into leaflets as in the case of the locust and horse-chestnut. Therefore, we may think of the locust as *pinnately compound,* and the horse-chestnut as *palmately compound.* In the first case the lobes or leaflets extend from a midrib and in the latter case from a common center.

Leaf arrangement. The arrangement of leaves on a stem is also a very helpful means of identifying trees. The place from which a leaf arises is called a *node.* When only one leaf arises at a node, the arrangement is said to be *alternate;* when two leaves arise, it is *opposite;* when more than two arise it is *whorled.*

LEAF ARRANGEMENT

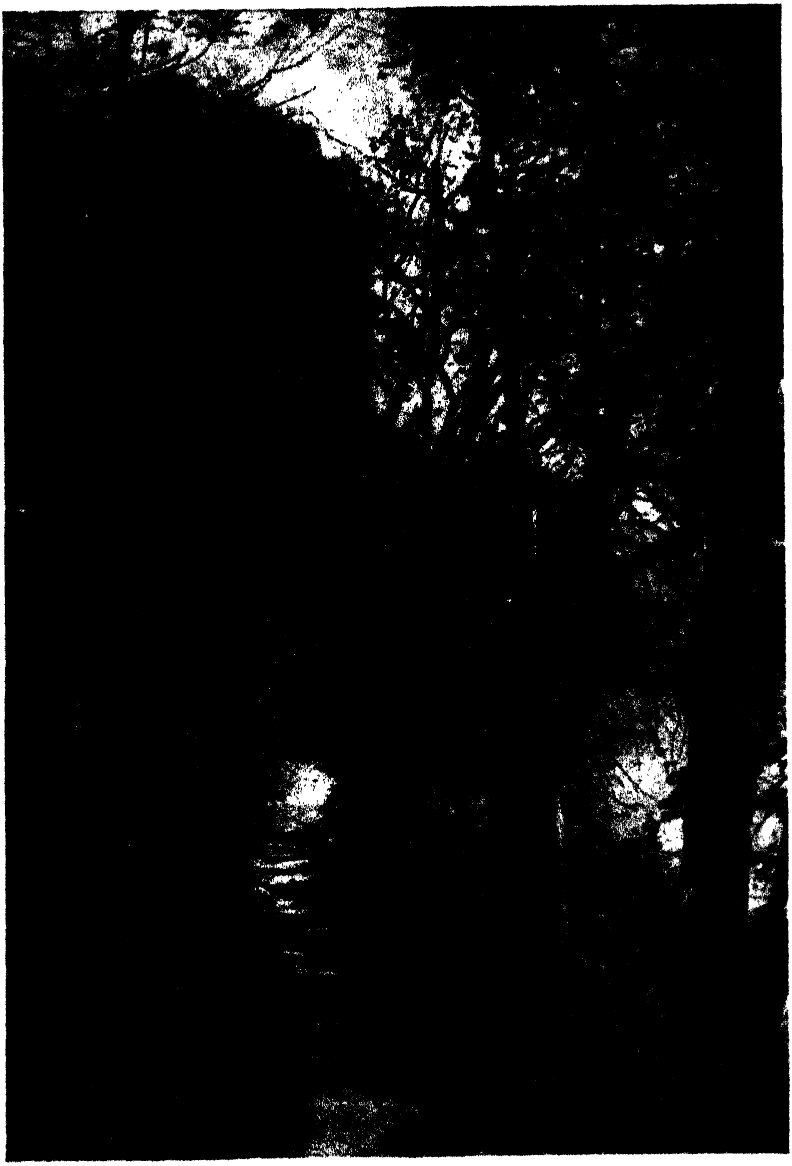




These drawings show the two most important types of leaf arrangement. Which type is shown in the drawing at the left? Which is shown above? What example can you give of each type?

Autumn, the season of all colors. Nothing is more beautiful than a forest in autumn. Every tree seems to try to put on a little show all its own. The maples are painted in lemon yellow, orange, red, and crimson. The oaks are colored in reds of various hues, interspersed with browns and bronze-greens. The nuts wear a beautiful yellow, and the poplars, pure gold. The colors of the trees are further enriched by those of the shrubs and vines, making the woodland a veritable art gallery.

A BEWITCHING ARRAY OF COLORS
A WOODS IN AUTUMN



Have you ever wondered how trees acquire their rich, glowing colors? These colors are really present in the leaves all the time. During the spring and summer, however, they are hidden by the green coloring matter of the chlorophyll. In the fall, when the leaves begin to die, the chlorophyll disappears, and the rich colors begin to show.

A GROVE IN WINTER.

Ewing Galloway

In winter the barren trees of a woods look somewhat like stately sentinels. Often snow and ice on the branches cause them to sparkle in the sunlight like jewels.

Autumn is also the season to study the fruits and seeds of many trees. Some trees, such as red maples, willows, poplars, and elms, shed their fruits and seeds in the spring. Others, on the contrary, keep them until the frosty nights of autumn. Among the trees that keep their fruits and seeds until autumn are rock maple, nut trees, and wild fruit trees.

Trees in wintertime. Strange as it may seem, one of the best times for studying trees, especially deciduous trees, is in the winter. Since there are no leaves to obscure the view, we can see what their shapes really are. A tree without leaves

may have any one of a number of shapes. It may have the appearance of a fan, a ball, a balloon, a triangular cone, an umbrella, or almost any other object, depending on its species. After we have observed its shape in winter, we can better understand what it is like in summer when it is covered with leaves. Then, too, nothing is more entrancing than a tree in winter, especially when it is covered with soft, velvety snow or glittering ice.

TREES TO LOOK FOR ALONG THE TRAILS

In our study of fish, fur-bearers, birds, and wild flowers, we considered only a few of the more common forms — just enough to stimulate us to a further study. Likewise, we must limit our consideration of trees to only a few of the more interesting and representative kinds. Then perhaps we shall wish to secure a manual on trees and pursue our study along nature's trails on a more extensive basis.

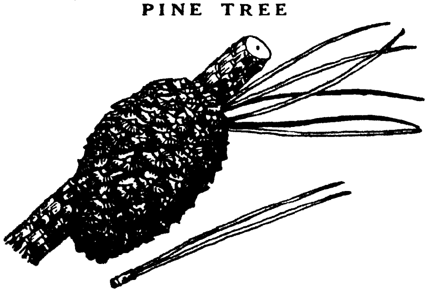
SOME INTERESTING EVERGREENS

A highly ornamental tree — the hemlock. Because of its beauty the hemlock is widely used as an ornamental tree in the eastern part of the country. It grows naturally from Nova Scotia to Wisconsin and Minnesota, and along the Appalachian Mountains southward to Alabama. Ordinarily it reaches a height of sixty to eighty feet and is about four feet in diameter. Its wood is soft and brittle, and is extensively used in making boxes, crates, and pulp. The most valuable part of the tree is the bark, which is used in the preparation of dyes and for tanning leather.

The hemlock is pyramidal in shape. Its limbs, which extend in a horizontal fashion, are covered with very beautiful foliage. The leaves are almost flat, about a half-inch long, rounded or notched at the apex, dark green and glossy above, but streaked with two white lines underneath. The cones are oblong, three-fourths of an inch long, and light brown in color. The most distinguishing characteristic of the hemlock is its tiny petiole or stalk of the leaf.

Valuable timber pines. The shortleaf pine is widely distributed throughout the South, being found southward from Pennsylvania to Florida and westward to Kansas and Texas. It is also called yellow pine, rosemary, or old field pine. Its straight, slightly tapering trunk, usually three or four feet in diameter, rises to a height of eighty to one hundred feet. Its shape, as well as the quality of its wood, makes it a very valuable tree for lumber. The needle-shaped leaves are five to nine inches long, blue-green in color, and arranged in clusters of threes. The cones or seed-bearing structures are two to six inches in length.

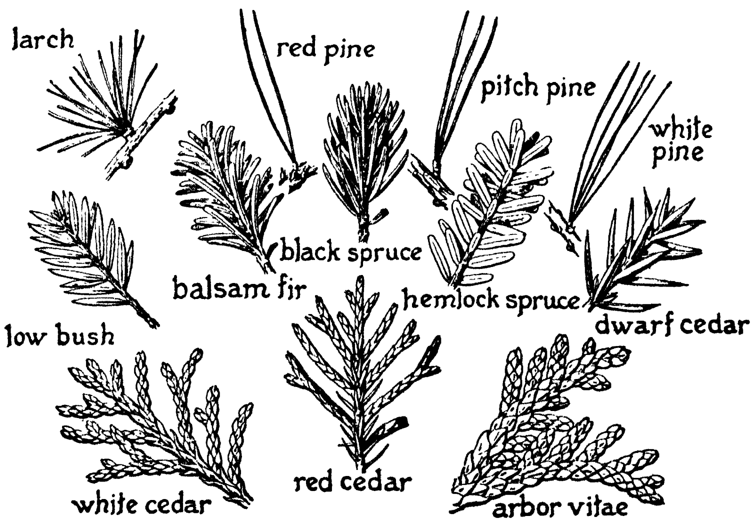
THE CONE OR FRUIT OF A PINE TREE



Courtesy Mississippi Forest Service

The cone or seed-bearing structure of a pine is from two to six inches long.

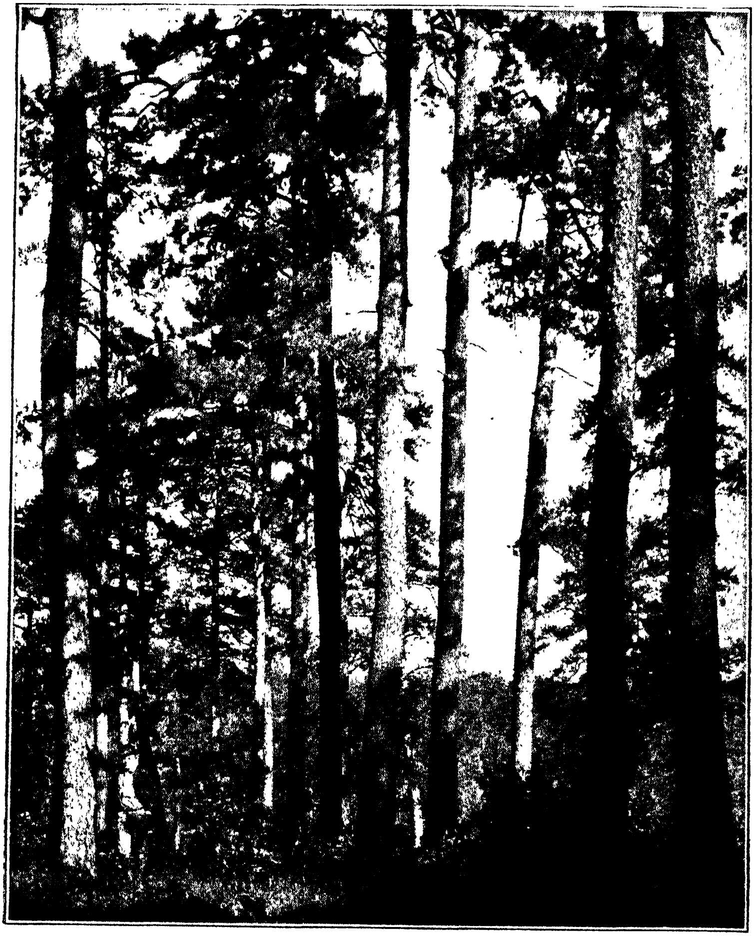
FOLIAGE OF THE VARIOUS EVERGREENS



Courtesy *New Wonder World*

How many members of the pine family have you identified along the trails?

A GROVE OF SHORTLEAF PINES



Courtesy U. S. Forest Service

When the shortleaf pines grow in a forest, their trunks grow straight and tall as shown in the picture. Usually the lower branches die off because they get very little sunlight.

The shortleaf pine, the Douglas fir, the western yellow pine, the white pine, and the hemlock, already described, are outstanding leaders in the lumber industry of the United States. These varieties of pine annually produce more lumber than all the other softwoods and the hardwoods combined.

AMONG THE REDWOODS

Courtesy U. S. Forest Service

This picture shows a highway cut through the heart of a redwood forest.

The giants of the evergreens — the sequoias. The sequoias are the largest and oldest of all living trees. There are two species of sequoias, the "big trees," which are found only on the western slopes of the Sierra Nevada, and the redwoods of the coast ranges. Some of the "big trees" are over three hundred feet high and more than thirty feet in diameter. The top is dome-shaped and clothed in evergreen foliage, from which hang small reddish-brown cones. The number of annual rings found on a cross section of some of these trees after they have been felled indicates that they have lived from eleven hundred to thirty-five hundred years. It is believed that some of the surviving trees are even from five thousand to eight thousand years old. Since the "big trees" are comparatively scarce and are such curiosities because of their size and age, several groves have been turned into national parks to insure their preservation. Here the trees are safe from harm.

MATCHING A TREE WITH HISTORY

Courtesy U. S. Forest Service

Following are some events that have happened while this yellow-pine log was growing:

1271—Marco Polo traveled in Far East
1295—First regular English Parliament
1338—Hundred Years' War began
1348—Outbreak of Black Death in England
1381—Wat Tyler's Rebellion in England
1415—Battle of Agincourt
1431—Joan of Arc burned at stake
1453—Constantinople taken by Turks
1462—First Bible printed
1492—Columbus discovered America
1513—Ponce de Leon landed in Florida
1534—Cartier discovered the St. Lawrence
1565—St. Augustine, Florida, founded
1588—Spanish Armada defeated by the English
1620—Landing of Pilgrims at Plymouth
1636—Harvard College founded
1683—William Penn made treaty with the Indians
1700—Yale College founded
1718—New Orleans founded
1759—Wolfe captured Quebec
1770—Boston Massacre
1775—Battle of Lexington
1803—Louisiana purchased from France
1831—First railroad built in the United States
1865—Lincoln's assassination
1867—Alaska purchased from Russia
1898—Spanish-American War

The redwoods live near the coast, where the fogs of the ocean keep the air moist. They grow from seeds and also reproduce by means of sprouts that spring up around the old trees. Since the trees are large, as much as forty thousand feet of lumber is sometimes obtained from a single trunk. Redwood lumber is particularly valuable because it resists the rotting effects of weather and water.

Some Deciduous Trees We Should Know

The most important of the hardwoods — the oaks. Of all the deciduous trees, the oaks are the most important.[1] They form one of the largest families, about fifty species being native to America and others to Europe and Asia. The acorn distinguishes them from all other trees. Their leaves are also characteristic, and most of them are lobed.

Chief among the American oaks is the white oak. It is easily identified by its pale-gray bark, its comparatively thick trunk, its broad, round crown, its finger-lobed leaves, and its characteristic buds and acorns. It is a large tree, growing tall in the forest but low and broad-crowned in the open field. In height it ranges from sixty to one hundred fifty feet, and in thickness from three to five feet. The white oak is admired not only for its beauty but also for its lumber, which is in great demand because of its durability, hardness, and fine color.

Trees with double-winged seeds — the maples. The maples are well scattered over the Northern Hemisphere, thirteen species being native to North America. The characteristics which mark the maples are their lobed and palmately veined leaves and their long-winged fruits.

One of the most popular maples is the red maple, so named because its slender branchlets have a soft reddish tint. In April it bears bright scarlet blossoms, followed in early May by scarlet-winged fruits. Its leaves, which are a rich green during the summer, turn red in autumn, making it stand out like a flaming torch. The red maple reaches a height of from eighty to one hundred twenty feet. Its favorite

[1] There are a few species of evergreen oaks in the South and West.

A GROVE OF SUGAR MAPLES

Courtesy U. S. Forest Service

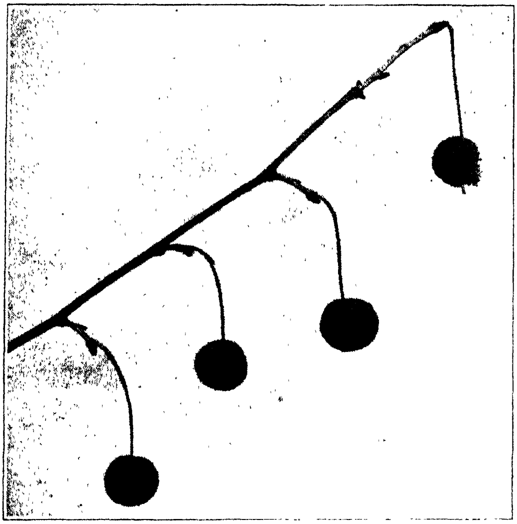
This picture shows a farmer gathering sap in a sugar camp. Later he will boil the sap to make it into sirup, or possibly into sugar. He will use some of the sirup on his own table and sell some of it for use in other parts of the country.

habitat is a rich, swampy lowland or a moist, fertile hillside. It is widely distributed in the eastern part of the country, sometimes being called scarlet, soft, or swamp maple. Because of its beauty and shade, it is often used for landscaping.

Another popular maple is the sugar maple, or rock maple, which grows in most of the northern states east of the Mississippi, especially in the New England states. This tree supplies a high-quality lumber prized for its beautiful grain and fine, satiny finish. It also supplies certain other important products made from its sap. When the white people first came to America, they found the Indians boiling maple sap to make sugar. Today the making of maple sugar has become a very important industry in this country. In the early spring a farmer "taps" his trees, that is, bores small holes into the sides and inserts spouts to carry the sap into buckets. He gathers the sap from these buckets and boils it in large vats or pans. This causes it to change into a thickened form known as maple sirup, or into a sugar known as maple sugar.

Trees that shed their bark—the plane trees. The trees that compose the plane-tree family are usually known as sycamores, but are sometimes called buttonwoods or buttonballs. The sycamores are found all the way from Maine west to Minnesota and Nebraska, and from Maine south to Florida and Texas. While they naturally grow along the borders of streams and in rich bottom lands where there is considerable moisture, they also grow well in the crowded quarters of cities, making beautiful trees for ornamental purposes. Their leaves are somewhat like those of maples, being palmately lobed. Their fruits are many-seeded balls that mature in the fall and hang from the branches throughout winter.

A GROUP OF "SYCAMORE BUTTONS" ON A WINTER BRANCH



Courtesy General Biological Supply House

The fruit of the sycamore grows in many-seeded balls that hang from the branches throughout the winter.

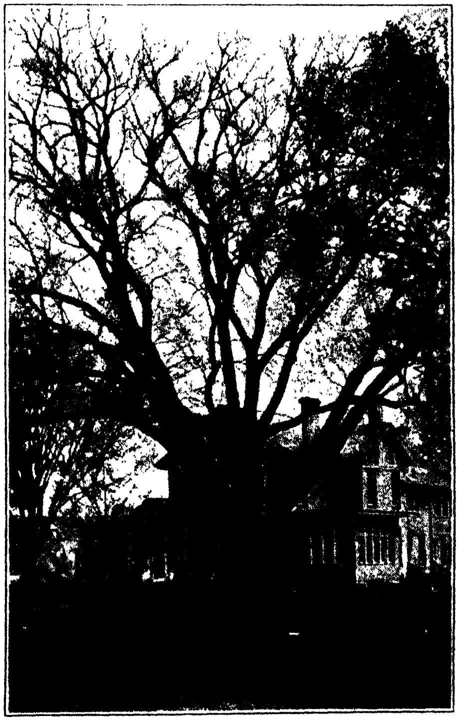
Sycamore trees are distinctive for two reasons: (1) They continually shed their bark, leaving an under layer exposed as white or greenish white patches; (2) they are large trees, being the largest deciduous trees in North America. A few years ago it was reported that a sycamore tree in Kentucky was so large that its hollow base was used as a home by a family including several children. George Washington on his surveying trip to the Ohio country in 1770 was impressed by the great size of the sycamores he found along the way.

The stately elms. The family of elms includes among its members the slippery elm, the American elm, the cork elm, the

English elm, and the Scotch elm. Of all the trees native to North America, the American elm is probably the best known and most admired. As a tree of history it shares honors with the oak. It was under the Washington Elm at Cambridge, Massachusetts, that Washington took command of the Continental army at the beginning of the Revolutionary War; and under the Treaty Elm on the banks of the Delaware that William Penn made his famous treaty with the Indians.

The American elm has a wide range and is adapted to many kinds of soil. It is graceful in appearance, often being used for shade and various ornamental purposes. It is a large tree, usually reaching a height of eighty to one hundred twenty feet and a diameter of four to eight feet. The shape varies, but ordinarily the trunk divides twenty or thirty feet above the ground into three or four main limbs, which spread out gradually, forming a fan-shaped top. The bark is dark and rough, with deep fissures and large diamond-shaped ridges. The leaves are four to six inches long, with veins running straight from the midrib to the double-toothed margins. The flowers, which occur in clusters, appear just before the leaves in early spring.

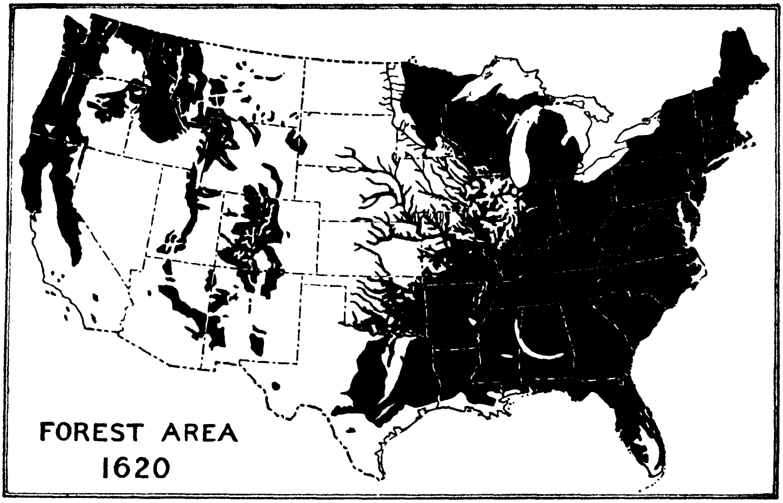
A FAVORITE SHADE TREE
THE AMERICAN ELM

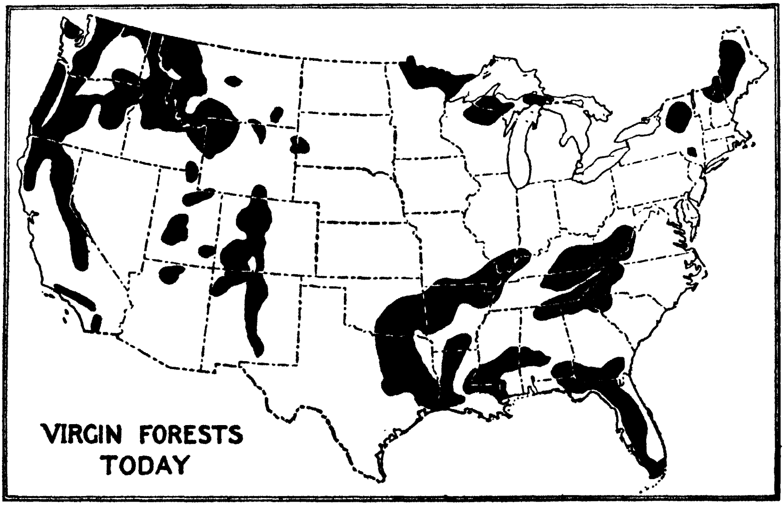


Courtesy Marietta Chamber of Commerce

This is said to be one of the oldest elms in the United States. Usually an elm has a much longer trunk and presents a fanlike appearance.

A PICTURE OF WASTE EXTENDING OVER A PERIOD OF 300 YEARS





Courtesy U. S. Forest Service

The darkened portions of the upper map indicate the regions in the United States that were originally covered by forests. The lower map shows the portions of these areas that still contain virgin forests. Certainly the reduction indicated in the second map proves that something must be done, and done soon, if we are to save what is left.

THE HEAVY DRAIN UPON FORESTS

Because of the immense quantities of lumber used each year and various destructive forces, such as insects, fires, and diseases, our forests are rapidly disappearing. Much lumber of course is wasted, but not nearly so much as formerly when it was more plentiful. At present forests are being used up and destroyed about four and one-half times as fast as we are replenishing them. When our forefathers first came to the shores of America, about 900,000,000 acres of land were covered with forests. Today only about one-fifth of this great area is still covered with trees. The maps on the opposite page show the change that has taken place. Let us analyze some of the forces that have resulted in this tragic depletion of one of our most valuable resources.

Man's great demands. It is estimated that we use in the United States about 23,000,000,000 cubic feet of timber every year. Thousands of acres of forests must be cut to satisfy this great demand. The following list shows some of the major ways in which lumber is used.

1. Railroads use about 130,000,000 new ties every year. Ties last on the average about eight years, but it takes 3,000 of them to lay a single mile of track.

2. Telephone and telegraph companies require 5,000,000 trees every year as poles to carry their wires.

3. The mining industries require 260,000,000 cubic feet of wood annually, mostly as props in the mines.

4. Paper mills require large quantities of lumber, especially spruce, in the manufacture of paper. It has been estimated that the annual output is sufficient to form a strip of paper the width of a newspaper that would reach halfway from the earth to the sun.

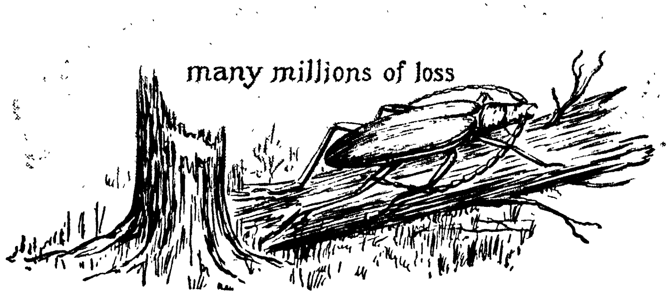
5. Farmers use about 500,000,000 wooden fence posts a year on their farms.

6. Furniture factories, lumber yards, and the manufacturers of many smaller products, such as lead pencils and toothpicks, require millions of feet of lumber annually. For example, we use a billion lead pencils every year.

The havoc wrought by forest fires. The destruction by forest fires in many parts of the United States is enormous, more timber being destroyed by fire than is put to use. In a recent year fires burned over a combined area as large as the state of New York. Many of these fires were caused by carelessness, mostly on the part of campers and tourists. Lightning also caused a great number.

The toll of insect pests. There are about 200,000 known kinds of insects that continually attack trees. These pests destroy thousands of acres of valuable forests every year,

ONE OF THE PESTS



Courtesy American Tree Association

Insects attack trees in a great variety of ways. Some eat the leaves, others eat or sting the fruit or seed, and still others bore into the cambium layer beneath the bark.

some attacking every part of a tree. It is estimated that they cause a loss of about $100,000,000 a year. Unfortunately, because of the great acreage involved, it is difficult to put up an effective fight against them.

The inroads of disease. Trees become infected with diseases that affect their health much as human beings become infected. When diseases in trees progress to such a point that the work of the roots, stems, or leaves is lessened or interrupted, the trees sicken and die. Such diseases as rusts and blights and the bracket fungi cause great losses among certain species of trees. For example, the chestnut blight has killed nearly all of the chestnut trees in eastern United States.

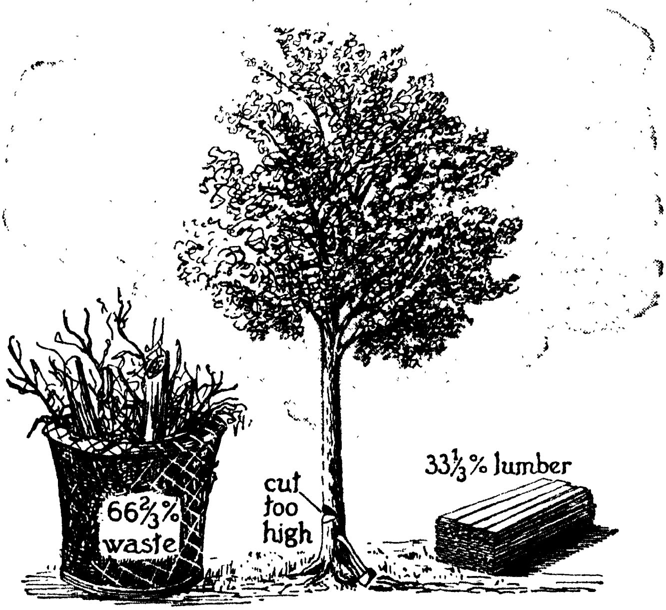
Other causes of depletion. Other forces that exact a heavy toll in forests are storms, winds, lightning, snow, and ice.

Storms and winds break limbs and uproot large trees; lightning splits trees and starts fires; snow and ice break down the limbs with their heavy weight. Grazing animals and rodents also destroy millions of small trees each year.

What We Can Do to Save Our Trees

Help to eliminate wastes. It is estimated that, on the average, two-thirds of the lumber in trees is wasted between the time when the trees are cut in forests and the time when

WASTE, THE CANCER OF THE FORESTS



Courtesy American Tree Association

Because of careless and thoughtless methods in handling and use, we sustain the appalling loss of 66⅔ per cent of our lumber products. How can this loss be prevented?

they are converted into finished products. Let us follow these trees to see what losses may be lessened or eliminated along the way. To begin with, they could be cut nearer the ground than they usually are. All available parts should be cut into logs or wood and not be left lying around to rot. At

the mill all the logs should be studied to see how they may be sawed to the best advantage. If the lumber is to be exposed to the weather, it should be treated with preservatives to make it last longer. All wastes and slabs should be used for making paper or other wood products. Fortunately, lumbermen see these needs and are bringing about corrections.

Strive to prevent forest fires. We should form the habit of making sure that every match lighted is put out before it is thrown away. Also, we should never leave a bonfire or campfire until we are sure that it is out or that there is no danger of spreading. Every fire means a loss of wood, whether in a forest or in the buildings of a city. It takes millions of dollars worth of lumber to replace buildings and furniture destroyed in city fires every year. Hence in country or city we should be careful in the use of fire. Every week of the year should be considered "Fire Prevention Week" and "American Forest Week," for

A FOREST RANGER ON HIS LONELY VIGIL

Courtesy U. S. Forest Service

This picture shows a forest ranger using a telephone to keep in touch with the outside world. He often leads a lonely life, sometimes seeing nobody for a period of several days.

there is nothing that is closer to our personal and national well-being than our forests and the products which they provide.

Fight insect pests. There are various ways in which we can fight insects. Many insects attack trees by eating the leaves. Their work is destructive because the leaves are the organs in which a tree manufactures its food. Therefore when insects strip a tree of its leaves two or three times, it usually dies. The foliage may be protected sometimes by placing a band of sticky material around the trunk. This band prevents the leaf-eating worms from crawling up the trunk and consequently keeps them away from the leaves. Some insects work under the bark of a tree and chew the cambium layer. When they have encircled the trunk, the tree dies. Therefore the bark should always be protected, for it helps to shield the cambium layer. Very few insects attack the bark itself. Still other insects bore into the wood, weakening a trunk or limb so that it is unable to withstand heavy windstorms. When a tree is trimmed, the fresh cuts should be carefully painted with tar or other protective substance. Such a protection helps to keep the insects out of the wood, and thus prevents their damaging effects.

Support a national program of conservation. Lumber is almost a necessity for our continued welfare. If we are to have lumber, however, we must actively support a program of conservation. Not only must we conserve the forests that are left, but we must also replace some of those that have already been cut. We must organize a reforestation program in such a way that we plant trees much as we plant crops on a farm. Each year we must plant a sufficient number to replace the trees that have been lost or removed. Many states have set apart a special day for planting, known as Arbor Day.

During recent years the federal government has taken particular interest in forestry problems, setting aside many national forests and coöperating with the various states in programs of conservation and reforestation. Few problems of government are more important than those related to

forestry, and we must ever be ready to help mold public opinion to the extent that the government may carry on the great work it has started. Our future depends largely upon the success of this movement. We must not become a nation without trees.

THE PART OF GOOD CITIZENS[1]

> A people without children would face a hopeless future; a country without trees is almost as helpless; forests which are so used that they cannot renew themselves will soon vanish, and with them all their benefits. When you help preserve our forests or plant new ones, you are acting the part of good citizens.
>
> THEODORE ROOSEVELT

SUGGESTED ACTIVITIES

I. Self-Organization Summary

A. Fish and Fishing

1. Make a list of some of the more important tips to anglers.
2. How is a fish adapted to a life in the water?
3. Describe in detail at least five of the fish you have studied in this unit.

B. Birds and Their Habits

1. How is a bird adapted to flying? Mention some of the ways in which it uses its feet and bill.
2. Prepare a three-column chart, listing ten birds in the first column, their feet adaptations in the second column, and their bill adaptations in the third.
3. Describe the family habits of at least five birds.
4. Classify the birds of this unit as to the type of resident—winter, summer, or permanent.

C. Trapping the Fur-Bearers

1. Describe three kinds of traps. Which is the most commonly used? Why?
2. Why are some of the fur-bearers said to be crafty? skillful?

[1]Courtesy American Tree Association.

3. Describe the more important fur-bearers discussed in this unit.

D. Wild Flowers
1. Name six wild flowers and list the characteristics by which they may be identified.
2. Explain briefly why wild flowers should be conserved.

E. Trees along the Trail
1. Select eight trees from this unit, classify as to evergreen or deciduous, and state the identification characteristics of each.
2. Why should you be concerned about a prógram of conservation and reforestation?

F. Saving Our Wild Life
1. Prepare a program that you think would be worthy of consideration to insure conservation of the various forms of wild life presented in this unit.

II. Committee Projects

Since there are five major problems in this unit, your class may want to break itself up into as many committees in order that each committee may make a detailed study of one particular form of life. Thus one committee may study birds, another fish, and so on. Through these committees you should arrange for exhibits, demonstrations, laboratory exercises, field trips, visits to museums and zoölogical gardens, special reports, and general discussions of particular topics.

A. Fish and Fishing
1. Study fishing as a sport. Examine fishing tackle and equipment and bring certain types to the classroom for examination. Explain how each type may be used. Locate various fishing "spots" in the community and tell what kinds of fish may be caught.
2. Prepare an aquarium containing several species of fish. Study their adaptations to a life in water. Observe the movements of their fins as they glide through the water. Watch them as they eat and breathe, and explain how these processes are carried on.
3. Bring in pictures of fish and mount them on cardboard. Use this chart for the purpose of identifying any fish you may catch.

4. Prepare special reports on such topics as unusual fish, deep-sea fishing, and conservation of fish.

B. Birds and Their Habits

1. Construct and distribute for actual use: bird baths, birdhouses, and feeding boards.
2. Prepare a large chart (bird calendar) with spaces for entering the names of birds as they are first seen in the spring, the places in which they are seen, and the dates of observations. This may be done either as a class or as an individual project.
3. Prepare a feeding chart on which to record the names of various birds and the types of food that they eat.
4. Make a number of field trips for the study of birds. Plan in advance just what you will look for. Take full notes of all that you observe.
5. Study the following topics, or choose topics of your own, for the purpose of giving special reports: Audubon, Agassiz, Alexander Wilson, bird migration, birds of unusual interest, conservation of bird life.

C. Trapping the Fur-Bearers

1. Arrange an exhibit of traps or prepare models of traps for catching fur-bearers. Explain the methods of using each type.
2. Secure specimens of furs from various sources, such as fur stores, and arrange an exhibit. Tell how each kind of fur is prepared for market.
3. Explain the intriguing sport of tracking certain animals. Illustrate with sketches.
4. Prepare special reports upon the life habits of fur-bearers of particular interest.

D. Wild Flowers

1. Prepare a herbarium of the most common and interesting wild flowers of your community.
2. Bring pictures of wild flowers and prepare a large chart. Use this chart for the purpose of identifying some of the flowers you find in the woods.
3. Make drawings to explain the functions of the various parts of a wild flower.
4. Prepare special reports upon any peculiar forms of flowers you find along nature's trails.

E. Trees along the Trail
1. Prepare an exhibit of leaves, fruits, wood specimens.
2. Collect pictures of trees and mount them on a chart. Use these pictures to help identify various trees you find in the forest.
3. Make a number of trips into the forest for the purpose of studying trees in their natural habitat. Have a definite plan of study and take detailed notes of your observations.
4. If possible, demonstrate various phases of tree surgery to show how decaying trees may be repaired and consequently prevented from dying.
5. Prepare special reports on Arbor Day and its significance, conservation, reforestation, modern methods of fighting tree enemies, or any other topic of particular interest.

REFERENCES[1]

1. Chapman, Frank M. *Bird Life.*
   a. The migration of birds, pp. 48–61
   b. The voice of birds, pp. 62–63
   c. Identifying birds, pp. 75–83
   d. The water birds, pp. 84–99
   e. The land birds, pp. 100–187
2. Eifrig, C. W. G. *Our Great Outdoors — Reptiles, Amphibians, and Fishes.*
   a. Habits of many of the game fish, pp. 109–217
3. *Flower Gardening.* Short Stories from the Farm and Garden Department, *Chicago Tribune.*
4. *Forestry Primer, The,* published by the American Tree Association, Washington, D. C. For free distribution.
   A pamphlet containing fourteen valuable lessons on conservation with respect to forests
5. Held, R. Johnson, and Rice, Edward Baldwin. *Angler's and Sportsman's Guide — How, When and Where to Hunt and Fish.* Any edition of the annual publication of Field and Stream Publishing Company, New York City.

[1]The pages listed here are those found in the editions indicated in the alphabetical list of references given at the end of this book.

6. Knight, John Alden. *The Modern Angler.*
   a. Equipment, pp. 9–16
   b. Casting, pp. 74–90
   c. Stream tactics, pp. 166–178
   d. Habits of fresh-water fish, pp. 178–189
7. Lynch, V. E. *Trails to Successful Trapping.*
   a. Baits and scents, pp. 24–30
   b. Restoring wild life, pp. 31–43
   c. Skinning and preparing pelts for market, pp. 138–144
8. Mathews, F. Schuyler. *The Book of Wild Flowers for Young People.*
   a. Spring flowers, pp. 3–93
   b. Summer flowers, pp. 193–219
   c. Fall flowers, pp. 243–389
9. Mathews, F. Schuyler. *Familiar Trees and Their Leaves.*
10. Parsons, Frances Theodora. *How to Know the Wild Flowers.*
    a. Notable plant families, p. 33
    b. Flower descriptions, pp. 1–321
11. Rogers, Julia Ellen. *Trees Worth Knowing.*
12. Seton, Ernest Thompson, *Lives of Game Animals.*
    a. Life of the red fox, Vol. 1, Part II, pp. 469–519
    b. Life of the grizzly bear, Vol. 2, Part I, pp. 3–81
    c. Life of the raccoon, Vol. 2, Part. I, pp. 129–257
    d. Life of the spotted skunk, Vol. 2, Part II, pp. 383–403
    e. Life of the mink, Vol. 2, Part II, pp. 517–561
13. Seton, Ernest Thompson. *Lives of the Hunted.*
14. Stevens, G. A. *Garden Flowers in Color. A Picture Cyclopedia of Flowers.*
15. Werthner, William B. *Some American Trees.*
16. *Book of Popular Science, The.*
    a. Game birds, Vol. 11, pp. 3583–3591
    b. The master craftsman — the beaver, Vol. 6, pp. 1815–1820
17. *Compton's Pictured Encyclopedia.*
    a. Traps and trapping, Vol. 14, pp. 127–130
    b. On the trail with the camera, Vol. 10, pp. 29–38
18. *Nature Magazine.*
    A magazine devoted to the outdoors. Each issue contains articles written by authentic students of nature that deal with topics considered in this unit.

19. *New Wonder World, The.*
    a. On the animal trail, Vol. 3, pp. 145–236
    b. At home with the birds, Vol. 3, pp. 295–368
20. *World Book Encyclopedia, The.*
    a. The story of angling, pp. 286–287
    b. Forests and forestry, pp. 2533–2541

If you are interested in hunting and fishing, you may enjoy reading such publications as the following:

Buck, Frank. *Fang and Claw.* Simon & Schuster.

Grey, Zane. *Book of Camps and Trails.* Harper Brothers.

Kiphart, Horace. *Camping and Woodcraft.* The Macmillan Company.

Mann, Paul B., and Hastings, George T. *Out of Doors.* Henry Holt & Company.

Solomon, Ben. *Hiker's Guide.* Leisure League of America.

Tose, Frank. *Trapping, Tanning, and Taxidermy.* Hunter, Trader, and Trapper Magazine Company.

VISUAL AIDS

Films (16 mm.)

A. Y. M. C. A. Motion Picture Bureau, New York City.
   1. Fish and Fishing for Everybody. 1 reel, silent, free.
   2. Battling with Muskies. 1 reel, silent, free.
   3. Where Beauty Dwells. 1 reel, silent, free.
   4. Fighting Forest Fires. 1 reel, silent, free.
   5. Canoe Trails through Mooseland. 1 reel, silent, free.

B. Eastman Teaching Films, Inc., Rochester, New York.
   1. Bird Homes. 1 reel, silent, $24.00.
      Gives close-ups of many birds and their homes in all types of habitats
   2. Wild flowers. 1 reel, silent, $24.00.
      Shows many common varieties in various stages of growth and in blossom
   3. Beavers. 1 reel, silent, $24.00.

C. U. S. Dept. of Agriculture, Washington, D. C.
   1. C. C. C. Fights Erosion. 1 reel, sound, free.
   2. Fur Industry of U. S. 3 reels, silent, free.
      Presents a survey of fur resources in the United States, including fur farms

UNIT NINE

HOW LIFE FORMS DEPEND UPON ONE ANOTHER

SUGGESTIONS TO THE TEACHER

The purpose of this unit is to show that one form of life depends upon another. Plants and animals work together in a great many ways. For example, they work together in bringing about a balance of oxygen and carbon dioxide in the air. This illustrates but one of many ways in which plants sustain the life of animals and animals in turn sustain the life of plants — a great cycle of interdependence. Moreover, both the plant and animal kingdoms present interesting partnerships in which one organism definitely associates with another for the purpose of giving some form of help. Some of the students may have encountered one or more of these partnerships in their own field of experience.

This unit, then, discusses various types of interdependence. It shows how two or more forms of life often form partnerships to help one another. It shows how all plants help to support animals and how animals help to support plants. The objectives of the unit are as follows.

OBJECTIVES

I. Facts and principles

A. To comprehend the peculiar adaptations by which life forms are interrelated, such as mimicry (including protective coloration), mutualism, parasitism, saprophytism

B. To learn how living forms prey upon one another and thus maintain a balance of power among species

C. To learn about a few typical life cycles that show the interdependence of organisms

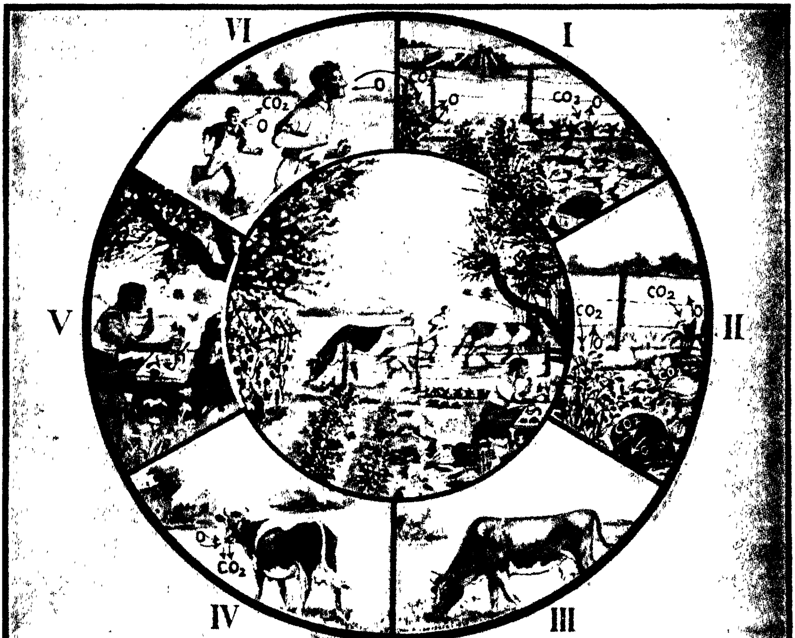
II. Attitudes

To appreciate the balancing processes that occur in nature, such as the prevention of an overabundance of certain species and the use and restoration of certain elements in the food cycles of plants and animals

UNIT NINE

HOW LIFE FORMS DEPEND UPON ONE ANOTHER

THE CYCLE OF LIFE IN THE PLANT AND ANIMAL WORLD



Courtesy *New Wonder World*

The familiar scene in the center is split up into six enlarged sections to show the story of life in the plant-animal world. In Section I the sun sends energy to the earth in the form of light and heat. In Section II plants stimulated by the sun's energy carry on the process of photosynthesis in which they take carbon dioxide (CO_2) from the air, hold the carbon, and give back the oxygen. In Section III an animal eats plants, thus getting carbon. In Section IV the animal breathes in oxygen. The carbon and oxygen meet in its body, resulting in the production of heat and energy and the giving off of carbon dioxide (CO_2) as waste. In Section V man eats plant and animal food and breathes in oxygen. The carbon and oxygen meet in his body, resulting in the production of heat and energy. In Section VI man breathes out carbon dioxide (CO_2) to be taken up by plants.

THE CYCLE OF LIFE

PREVIEW

According to the plan of this world of ours, death is always a sequel to life. The author, William Cullen Bryant, in his memorable poem "Thanatopsis," has shown the relationship between life and death in the following beautiful lines:

> Earth, that nourished thee, shall claim
> Thy growth, to be resolved to earth again
> And, lost each human trace, surrendering up
> Thine individual being, thou shalt go
> To mix forever with the elements,
> To be a brother to the insensible rock
> And to the sluggish clod, which the rude swain
> Turns with his share, and treads upon. The oak
> Shall send his roots abroad, and pierce thy mould.

There are two factors necessary for life: first, matter, composed of elements, and second, energy, which provides the power to carry on life processes. Scientists have found that matter in all its forms is composed of ninety-two elements. The various combinations and associations of these elements provide all the material things in the universe. Ten of them[1] provide the building materials of plants and animals.

There are no animals that possess the power of taking these elements in their natural state and manufacturing them into living substances. This wonderful process has been reserved for green plants. They have the power of catching the sun's rays and utilizing them in the manufacture of food from elements found in the earth, air, and water. Thus the energy of the sun transforms the elements of nature so that they may be used by living things for the maintenance of life. Then, as these living things die, the elements that compose their bodies return to the earth, air, and water from which they originally came. Thus it is that the cycle of life keeps going. No elements are ever lost; they merely keep moving, changing

[1] The ten elements necessary for growth are oxygen (O), carbon (C), hydrogen (H), nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), iron (Fe), and magnesium (Mg).

their homes and combinations as they pass from the soil, the water, and the air into the plants and finally into the animals. From the plants and animals they later return to the earth, air, and other places from which they came.

The cycle of life and death may be illustrated by what happens to plants and animals of the forest. A caterpillar, for instance, feeds upon the green leaves of a tree. A wasp kills and eats the caterpillar, and a beetle in turn consumes the wasp. A hungry bird, seeing the beetle, consumes it and flies on its way. Later the bird dies and certain ants give its body a crude burial by carrying its body, bit by bit, underground. The body disintegrates and the elements of which it is composed return to the soil, making it rich enough to supply food for a growing tree. Another caterpillar feeds upon the leaves of the tree and a new cycle is under way.

The following problems will be treated in such a way as to reveal more clearly this ever revolving plan of nature.

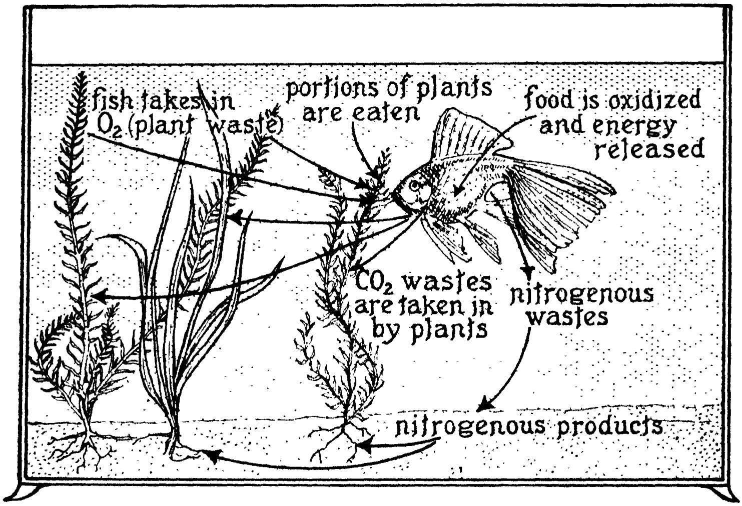
PROBLEMS

1. **What interdependencies exist between green plants and animals?**
2. **What interesting partnerships are formed in the plant and animal kingdoms?**
3. **What are some of the parasites among plants and animals?**
4. **How do some plants and animals survive as the result of special adaptations to their environment?**
5. **How do certain plants and animals capture and kill their prey?**

Problem 1. What interdependencies exist between green plants and animals?

The *balanced aquarium* in the home or school affords an excellent example of the relation that exists between green plants and animals. In such an aquarium we see a little world complete in itself. Let us peer through the glass walls that encompass this miniature world and see whether we can

BALANCE IN AN AQUARIUM



The plants in the aquarium in the process of photosynthesis give off oxygen and produce such foods as starches, sugars, and proteins. The fish breathes the oxygen and eats the foods. Oxidation takes place within the body of the fish and the foods are converted into animal tissues, energy, and wastes chiefly in the form of carbon dioxide and nitrogenous matter. These wastes are taken up by the plants through their leaves and roots. A second time the plants give off oxygen and produce foods. In this manner, a cycle of interdependence is continually in progress.

understand the principles involved in keeping it balanced. This is important because we shall find these principles are the same as those that operate in the great outside world.

When the aquarium is balanced. The green plants in the aquarium require carbon dioxide (CO_2) and water (H_2O) just as trees, grasses, and other land plants do in order to carry on photosynthesis, or the manufacture of sugar. The carbon dioxide is given off into the water by the animals and then taken in by the plants. For the manufacture of proteins, plants need nitrogen. This is obtained from the solid nitrogenous animal wastes which are dissolved in the water. Thus the animals provide the very elements the plants need, carbon dioxide and nitrogen. In return the plants give off into the water oxygen, which is a by-product of photosynthesis (food making). This oxygen is absorbed and utilized by the animals. Fish and snails in the aquarium eat portions of the water

plants, which readily grow and multiply in their favorable environment. Hence when the plants and animals are in proper balance, the wastes of the one help to sustain the life of the other. That is, there is a continuous exchange in which nothing is lost but in which the same elements are used over and over.

When the aquarium becomes unbalanced. If too many animals are placed in the aquarium, the plants are not able to utilize all of the animal wastes. Consequently the water becomes murky and gives off an unpleasant odor. The fish become restless and push their noses above the surface of the water in search of oxygen. Finally, unless the water is changed and more plants are added, the animals will die from a lack of oxygen and the poisons from their excess wastes.

When the aquarium is balanced, the water is clear, there is no odor, the animals are contented, and all is well in their world. A similar balance is necessary in our world for proper continuance of life. Nature has many schemes for maintaining this balance, some of which are presented later in this unit.

Problem 2. What interesting partnerships are formed in the plant and animal kingdoms?

We have learned that certain plants need bees to carry pollen grains from one flower to another, and that in return for their timely services the bees receive pollen and nectar. Millions of birds get food and shelter from the trees, which they protect from the ravages of insect pests. Even the plants and animals in an aquarium help one another and maintain a separate little world of their own. Similar dependencies exist everywhere in the world. On the following pages we shall consider a few of the most interesting.

PECULIAR PARTNERSHIPS

Odd partners in the animal world. The living together of different organisms in a form of partnership is called *symbiosis* (sĭm′bī-ō′sĭs). When the partnership is mutually advantageous, it is known as *mutualism* (mū′tṳ̄-ăl-ĭz′m).

Partners in the Animal World

The sea anemone and the hermit crab. One of the best examples of mutualism among animals is the partnership of the sea anemone and the hermit crab. Each animal has certain handicaps that are overcome by the partnership. The hermit crab is a peculiar little animal with a soft body and no armor to protect itself. Its first responsibility is to seek some form of shelter; hence, it moves into the cast-off shell of some such creature as a salt-water snail. Then as it increases in size it moves into a larger shell. With such protection it can crawl about from place to place in the water in comparative safety. Throughout its whole life, then, the hermit crab lives in a borrowed home which it carries with it wherever it goes.

Sooner or later, while crawling about, the hermit crab approaches a sea anemone, which is usually attached to a rock, takes hold of it with one of its claws, and places it on the borrowed shell. There the sea anemone settles down and accompanies the hermit crab on its wanderings. With its tentacles, which are equipped with stinging cells, it paralyzes various animals and thus provides protection for the hermit crab. In return for this protection the hermit crab transports it from one feeding ground to another. In its food the sea anemone is limited to the small animals that come its way. The illustration on page 41 shows how the hermit crab transports the sea anemone in their partnership of mutual helpfulness.

AN ANT AND ITS COW AN APHID

Courtesy American Museum of Natural History

What mutual benefits are derived from the partnership relation of these insects?

The ants and their "cows." The queer partnership of the ants and the aphids (ā′fĭdz), or plant lice, is one of the most interesting cases of mutualism in the animal world. The aphids feed on the tender branches and

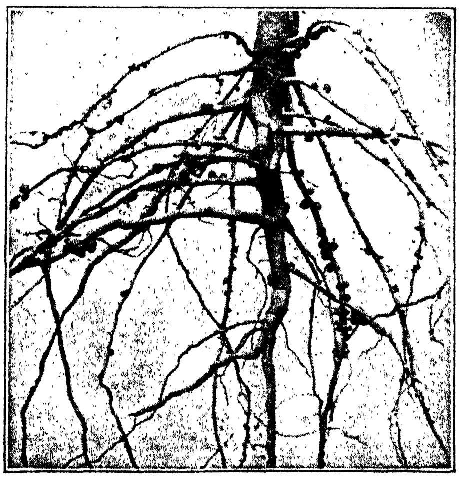
leaves of plants by thrusting their bills, or sucking tubes, beneath the surface and drinking sap. When stroked on their backs by the antennae of ants, they excrete a few drops of a sweet substance called honeydew, a good food for the ants. Thus the aphids serve as "cows" for ants.

In return for the honeydew, the ants do many things for their aphid "cows." They rush to their aid when they are attacked by an enemy, and try to carry them away to safety, even at the risk of their own lives. In the fall they care for the eggs of the aphids by bringing them to their own nests for the winter. In the spring they drive the aphids (cows) to plants (pastures) where they may obtain food. Here they watch over them in droves much as cowboys watch over herds of cattle on the plains.

Partners in the Plant World

Nitrogen bacteria and the clover plants. If we should go to any field in which clover plants or other legumes are growing and pull up some of the roots of these plants, we should find little swellings or nodules scattered about on them. Each nodule serves as a home for millions of nitrogen-fixing bacteria. In return for "room and board" in the plant nodules, the bacteria render certain valuable chemical services to the plants. They change the nitrogen which they take from the air in the soil into nitrogen compounds which the plants can use.

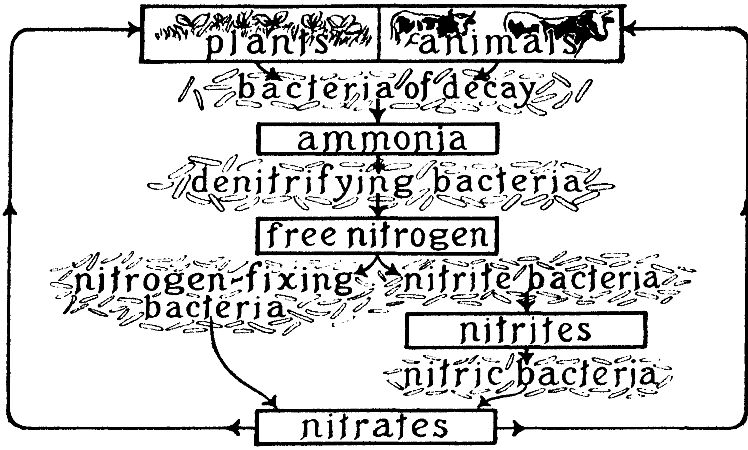
A HARBOR FOR NITROGEN-FIXING BACTERIA



Courtesy U. S. Department of Agriculture

The nitrogen-fixing bacteria live in the nodules or tubercles on the roots. They produce nitrates which the plant uses in building its own tissues.

HOW PLANTS AND ANIMALS DEPEND UPON EACH OTHER FOR NITROGEN



Nitrogen, like oxygen, is essential to the growth and repair of all living things. Neither plants nor animals, however, can take it directly from the air. Plants get nitrogen through soluble compounds in the soil or by the action of nitrogen-fixing bacteria. These bacteria live in nodules on the roots of certain legumes, such as clover, alfalfa, and peas. They take nitrogen directly from the air and combine it with other substances to form nitrogenous compounds or nitrates which the plants can use. The animals get most of their nitrogen by eating plants that have stored it away during growth.

Problem 3. What are some of the parasites among plants and animals?

Just as certain members of the human family prey upon society for a living, certain members of the plant and animal kingdom depend upon other living organisms for the necessities of life. Such dependent organisms, as we have already learned, are known as *parasites* (păr′ȧ-sīts). A parasite, then, is an organism that depends upon another for a living.

Some parasites, as bacteria, are too small to be seen by the naked eye. Indeed, we know that they exist only because of their effects. Many parasites, on the other hand, are readily apparent. The insect world, for example, contains numerous parasites, and if it were not for the continual battle among them, man would suffer more than we can realize. As a result, parasites in many cases are really great friends of man.

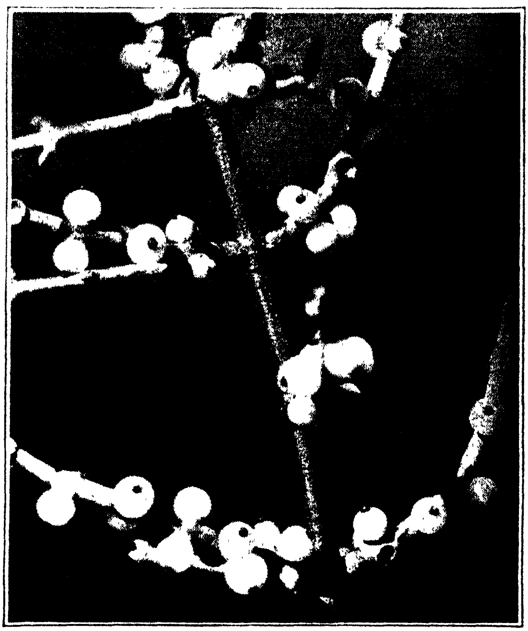
DEPENDENCY AMONG THE PLANTS

Dependent plants are divided into two general groups, *parasites* and *saprophytes* (săp′rō-fīts). A parasite, as we know, is a living organism that exists at the expense of another living organism known as its *host.* Such a relationship is the direct reverse of mutualism. A saprophyte differs from a parasite in that it lives on dead rather than living organic matter.

TWO KINDS OF DEPENDENT PLANTS

Only a partial parasite — the mistletoe. There are, of course, different degrees of parasitism. Some plants are only *partial parasites,* as the mistletoe, which lives on certain trees in several southern states. Its sticky seeds cling to the feet or bills of birds and are deposited on the branches of a tree. The seeds germinate and each young plant sends root-like threads into the branches of the tree. Thus it obtains water and minerals from its host as if it were growing in the soil. The leaves of the mistletoe, however, take in

THE MISTLETOE



Courtesy *Nature Magazine*

Although the mistletoe takes water and minerals from its host, it manufactures its own food and does not kill the plant upon which it takes up its abode. Since it does not depend entirely upon its host, it is known as a partial parasite.

[1] Certain parasites that live in the body of man are discussed along with bacterial diseases in Unit Three.

carbon dioxide and manufacture food. Thus the mistletoe may be called a partial parasite, because it makes its own food from raw materials obtained from its host and from the air.

The plant that is forced to prey — the yellow dodder. The yellow dodder is a plant that gets its entire food supply from its host. Its seeds develop in the ground just as do those of any ordinary land plant. Up from the ground grows a slender, threadlike leafless stem which sweeps about in the air until it touches a plant. If it makes contact, it will live, but if it fails, it will die after two or three days. Thus its chance of surviving is very uncertain.

THE YELLOW DODDER

L. W. Brownell

The dodder clings to its host by means of yellow threads which it winds around the leaves and stems. It is a perfect parasite, taking all of its food from its host.

Let us observe the "porch-climbing" tactics of the yellow dodder. It begins by sweeping about until it finds a clover or some other plant, and then makes itself secure by twining around the stem. As it does this, it sends rootlike processes into the plant and saps the life juices of its victim. Finally it gives up connection with the earth and its roots completely wither away.

Plants that live on fruits and vegetables — the molds. The most destructive plant parasites are members of the *fungus*

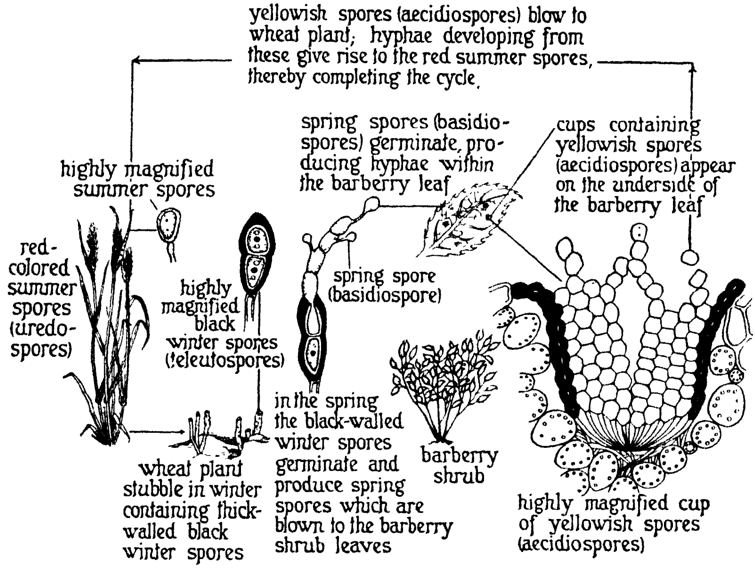
group. Among these fungi are the *molds*, which are parasites on fruits and vegetables. The tiny spores of these molds are able to survive great extremes of heat, cold, and dryness. When they fall upon plant tissues, they germinate by sending out little threads called *hyphae* (hī′fē), which branch out into a mat of threads called a *mycelium* (mī-sē′lĭ-ŭm). After two or three days the mycelium sends up numerous tiny branches. Soon the tips of these branches develop small rounded sacs containing dozens of spores. The great spore-producing capacity, the rapid development, and the power to break down tissues upon which they live combine to make molds exceptionally destructive.

Plants that injure grains — the rusts. *Rusts* are tiny parasitic members of the fungus group which are responsible for serious diseases affecting certain cereals, such as wheat, rye, barley, and oats. They are found wherever cereals are grown, and cause millions of dollars' worth of damage to crops every year. They live inside the host plants and injure or destroy the tissues concerned with the manufacture of food.

The wheat rust is the most widely known of the group. It is an unusual parasite, for it lives on two hosts. Its life history is interesting to follow. In the late spring and early summer it appears as red spores on the leaves of the wheat plant. These red spores infect other wheat plants, and the red rust spreads. Then later in the summer black spores appear on the stems. These black spores spend the winter in the dead wheat stubble. In the spring they germinate and produce spores, after which a most unusual thing happens. The young spores do not infect the new wheat plant immediately but take up a parasitic existence upon the leaves of the common barberry. Soon the fungus can be detected by cuplike depressions that appear on the leaves. From these cups yellowish spores are shed, and again a strange thing happens. The new spores attack the wheat plant and produce further rust.

The destruction of barberry plants in several of the northern states has somewhat reduced the damage of wheat rust. Since the rust grows on two hosts, barberry and wheat, and

THE LIFE STORY OF STEM RUST OF WHEAT



What is the relation of the barberry plant to the reproduction of stem rust in wheat?

on the inside of its hosts, it is very difficult to control. More and more study, however, is being given to it, and doubtless within a few years ways will be found to bring about its complete destruction.

Other grain parasites — the smuts. *Smuts* (smŭts) are other members of the group of parasitic fungi. They develop most commonly on corn, oats, barley, and wheat. Their spores live from one year to the next in the soil or on the seeds or grains. When the seeds are planted, the spores germinate and infect the young plants. Like the rusts, smut plants live within their hosts. They may be found in the root, stem, leaves, or seeds. One of the best methods of killing spores on seeds is to soak the seeds in a weak solution of formalin. In this manner the spores may be killed before the seeds are planted. Another method of combating smut is to burn the plants in the fields as soon as evidence of the disease appears.

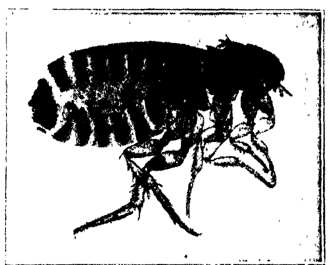
Plants That Live on Dead Organic Matter—The Saprophytes

Plants that act as scavengers. By living on dead organic matter, *saprophytes* help keep the earth's surface in a suitable condition for living things. Mushrooms, for example, help to return to the soil the dead stumps of trees so that the elements composing them may again be utilized to support life. Most saprophytes are bacteria and fungi.

ANIMALS THAT ARE PARASITES

Nearly every animal is infested with certain other animals that prey upon it. *Plasmodium malariae*, the tiny *sporozoan* (a protozoan that reproduces by spores) that causes malaria in man, is one of the smallest but most dangerous parasites. Fleas, lice, bedbugs, ticks, and chiggers are called *external parasites*. They secure their food by burrowing into the skin of their hosts with their strong mouth parts and sucking blood. Then, too, they are harmful because they often transfer the blood of a diseased animal to a healthy one. For example, cattle ticks transfer a sporozoan parasite that produces Texas fever in cattle and causes an annual loss of about $100,000,000 in the United States.

AN EXTERNAL PARASITE



Courtesy Max Poser, Bausch & Lomb Optical Company

The cat flea (here greatly magnified) sucks the blood of the cat.

Some of the *internal parasites* are the tapeworm, the hookworm, the liver fluke, and the trichina (trĭ-kī'nȧ) worm. The parasitic habits of some of these worms are discussed in Unit Seven under worms.

Many parasites are in turn preyed upon by other parasites, a theme that is expressed in an amusing old-time verse:

Great fleas have little fleas
  Upon their backs to bite 'em,
And little fleas have lesser fleas,
  And so ad infinitum.

Problem 4. How do some plants and animals survive as the result of special adaptations to their environment?

Many a clever device exists in nature for the protection of life forms. The animals of the desert, of the tropical forest, of the Arctic region, and in fact of any section of the earth, are in some manner provided with means of protecting themselves against their enemies.

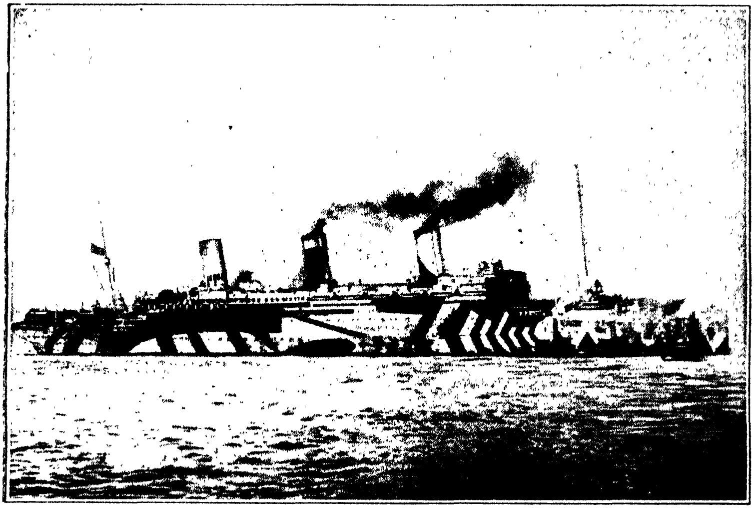
HOW ANIMALS SURVIVE BY MIMICRY

Protective mimicry, which is a form of protection provided by nature, appears in two major ways: first, animals may be so *colored* and shaded that they blend with their surroundings, thus being rather difficult to see even at short distances; second, they may be so *shaped* as to resemble other objects in their environment and thus be unnoticed by enemies that may approach.

It must be understood that the protection afforded by mimicry of color and shape is not due to any deliberate plans of the animals themselves. The polar bear, for instance, did not get its white fur by thinking it should have a coat to match the snowy background of its native land. On the contrary, protective mimicry has come about very slowly as a result of the efforts of nature to safeguard her children.

The story is different, however, as far as man is concerned. He has used his intelligence in planning a wide use of protective mimicry. To illustrate, in early days soldiers went to war in brightly colored uniforms. Arrayed in such raiment, they stood out in sharp contrast to the dull colors of their surroundings, thus making themselves excellent targets for the enemy. Today American soldiers wear an inconspicuous khaki uniform which blends with a background of earth and rocks. In the World War (1914–1918) a form of protective mimicry known as *camouflage* (kăm′o͝o-fläzh) was employed as an important method of defense. The word "camouflage" is an old one used among French painters and means "to falsify in painting."

AN EXAMPLE OF CAMOUFLAGE



This picture shows how some of the warships were painted during the World War to give them a deceptive appearance. You can readily imagine how the broken patches on the sides blend with the foam of the sea and render ships indistinct.

French artists first conceived the idea of using this type of mimicry as a defense in war. Today ships are painted in dull colors with broken patches and wavy lines which give them the appearance of waves and clouds. Artillery pieces, tanks, observation posts, and other kinds of war equipment are successfully hidden by camouflage.

Protection by color deception. If we have ever tried to find a noisy katydid in the grass or to locate a bobwhite that has called from a field of wheat stubble, we can understand how well their disguise protects them. The most useful coloring for animals whose lives are spent trying to avoid their enemies is that which will make them least conspicuous. The particular coloring is, of course, dependent upon the nature of their haunts, as illustrated by the katydid and the bobwhite.

The best examples of protective coloration are found among the most helpless animals—those that have little or no other means of defense. Thus most of the small swimming creatures of the sea are transparent, and consequently protected from

their enemies. Most of the fish with which we are familiar have backs of dark blue, a color not readily seen under water.

Insects, birds, and fur-bearers exhibit interesting studies in protective coloration. Many of the insects that live and feed amid the foliage of trees and shrubs or in grass and weeds are protected by their green or mottled-green coats. Those that inhabit dry, parched lands and deserts are dull colored or spotted, and many of them have the same color as sand. Moths are active at night when they cannot be seen by their enemies. During the day when they are at rest, they are protected because of a close resemblance to their surroundings. Moths invariably choose a resting place with a background that harmonizes with their own coloration.

A PUZZLE PICTURE

Lynwood M. Chace

So perfectly do the marks on the woodcock resemble her surroundings that you could almost ask, "Where is she?"

The polar bear is white all the year round. Being a meat eater, it can live well in the land of perpetual ice and snow, for fish and seals are always available. Its white coat hides it from hunters as well as from its prey. The Arctic fox and the Arctic hare stray from the regions of ice and snow and change their color with the season.

An interesting study of concealing coloration may be made by observing the bird life in any community. Such brilliantly colored birds as the orioles, tanagers, and warblers are ordinarily shy and do not permit us to approach them closely. However, those that are protectively colored, such as the meadow larks, sparrows, and shore birds, will often allow us almost to touch them before taking wing. The screech owl sitting in the daytime on a dead tree seems a part of it. The snow bunting, with its coat of white feathers splashed with

A PROTECTION FOR THE TIGER

Ferdinand Hirsh

The natural habitat of the tiger is an area of tall grasses such as shown above. Its stripes so closely resemble the blades of grass that it comes upon its prey unnoticed.

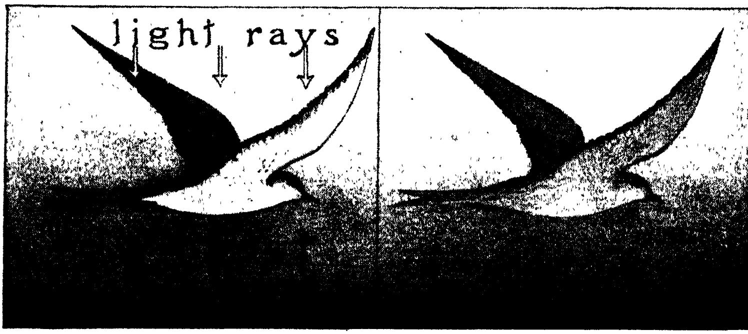
patches of darker color, blends nicely with a background of snow-covered bushes. Usually the male of any species of birds has brighter colors than the female of the same species. Scientists often explain the dull coloration of the female as an attempt of nature to protect her while she is building her nest, incubating eggs, and caring for her young.

Although the purpose of coloration more often is to protect animals from their enemies, sometimes it is an aid to them in search of prey. Thus the weed-brown snapping turtle, the muddy crab in the eelgrass, and the alligator that looks like a floating log are able to capture their prey from ambush. The stripes of the tiger, matching the streaks of sunlight and shadow

in tall grass, provide a disguise that permits it to lurk unnoticed until some unsuspecting victim comes near enough to be seized.

Making colors blend together—counter-shading. Some animals are protected by a blending of colors known as counter-shading. This means that they blend into their environment because light and shadows tend to make their darker parts appear lighter and their lighter parts appear darker. In other words, light and shadows soften the colors, making the animals less distinct. This type of protection means a great deal to birds, as indicated in the pictures below.

COUNTER-SHADING ON BIRDS



The light from above makes the top of the bird lighter in color, and shadows from below make the lower part darker, as shown at the right.

Deception by imitation of form. In the battle for existence a weaker animal often takes on a resemblance in form to a stronger or more aggressive animal. This resemblance is a protection to the weaker animal because it is often mistaken for the animal it resembles and consequently goes unharmed. The similarity of form probably comes about by gradual changes from one generation to another in which animals of a weaker species take on the characteristics of a stronger one. It is probably in this way that a butterfly known as the viceroy has come to imitate a larger species known as the monarch or milkweed butterfly. The monarch has large reddish-brown wings with black veins, a peculiar odor, and evidently an unpleasant taste. The viceroy has grown to resemble the

monarch so closely that the birds can scarcely tell them apart, and consequently leave both of them alone.

Some insects resemble flowers and leaves, and others even resemble sticks. In each case the object mimicked is one which the insect's enemies avoid or are not interested in. Insects that prey upon other insects often take on the characteristics of something attractive to their prey. Certain spiders that live in flowers are colored like the flowers. This makes it possible for them to remain hidden waiting to seize as prey various unsuspecting insects that commonly come for pollen and nectar.

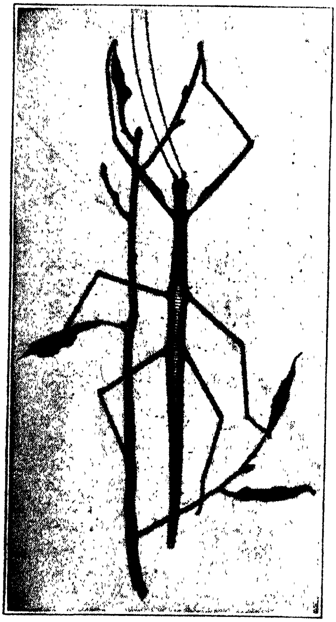
BUTTERFLIES THAT RESEMBLE LEAVES

When its wings are folded at rest, the leaf butterfly (Kallima) of East India resembles a leaf. Can you find the one near the top of the picture? the one near the bottom?

The leaf insects are remarkable in that their similarity to leaves is almost perfect. When they first hatch, they have a reddish color that makes them appear like buds. Then, as they begin to feed, they change their color to green, and take on markings that resemble the veins of a leaf. As they grow older, they

continue the mimicry by taking on rust-colored spots and markings similar to those of a leaf when it begins to decay. Thus the mimicry is complete.

AN ANIMAL THAT IMITATES A TWIG



Courtesy *World Book Encyclopedia*

Certainly the walking stick profits by the mimicry shown in this picture.

Stick insects, so called because of their long and slender shape, can fold their legs up tightly against their bodies so that they look exactly like twigs or splinters. Their unusual form, together with a coloration of gray, brown, or green, renders them almost invisible to their enemies and to their prey.

Animals that change their make-up. The champion "turncoat" among animals is a lizard known as the chameleon (kȧ-mē′-lê-ŭn). This colorful little creature at a moment's notice changes its make-up from a brilliant green to a gray-black or to a chestnut and black, or it appears to be covered with yellow spots. Thus as a means of protection from birds and snakes it makes itself inconspicuous by taking on the color of its surroundings. The color changes are brought about by layers of cells beneath its transparent skin that contain yellow, black, and red coloring matter. These cells are partly under the control of the nervous system, and changes in coloration are produced by contraction and expansion.

Certain tropical fish, among them the Nassau grouper (năs′ô grōōp′ẽr), which normally is brilliantly colored, turn dark when alarmed and rush for shadowy hiding places. Minnows, sticklebacks, and trout also have the power of changing their color. Interestingly, too, at times an ordinary frog alters somewhat the tint of its skin.

PROTECTION FOR CACTUS PLANTS

The picture shows an assembled group of cactus plants. The spines of such plants not only help to retard evaporation but repulse the attacks of grazing animals.

HOW PLANTS AND ANIMALS SURVIVE BY CERTAIN DEFENSES

A life worth living always means some struggle or endeavor. This is even true of plants, and we find that many of them have built up strong means of self-protection. Some, for instance, have developed defenses against the attacks of grazing animals. These defenses consist of *mechanical weapons,* such as thorns, spines, prickles, and stinging hairs, and *chemical weapons,* such as poisons and irritating acids. As a result, animals learn to leave such plants alone.

Among animals the struggle against enemies is much more marked, for they continually invite danger as they move about. The following outline includes a few of the many animals that are equipped to defend themselves.

INTERESTING ANIMAL DEFENSES

ANIMALS	MEANS OF DEFENSE
Armadillo	Bony plate covering that permits the animal to roll up into a ball
Bee, wasp	Stinging organ that injects formic acid
Birds	Rapid flight and in some species sharp bills and claws for fighting.
Bombardier beetle	An ill-smelling, irritating substance given off to make it distasteful
Fish	Armor plates, as in the bony pike of North America and the boxfishes of the warm seas; electric shocks, as in the ray or skate and the electric eel; a poison gland connected with the pectoral spine, as in some of the bullheads and catfish
Gila monster	A poison coming from the lip glands; a stony, bead-like skin
Goat, cattle, deer, moose	Horns and antlers
Horse, mule	Powerful hind legs for kicking
Jellyfish	Stinging cells
Octopus, cuttlefish, squid	Ink-throwing glands that produce a protective "smoke screen" (See the illustration on the opposite page)
Oyster, clam, snail	Shell coverings
Rattlesnake	Poison which it ejects through two perforated teeth or fangs
Rhinoceros, hippopotamus	Tough, thick skin as protection from flesh eaters
Sea urchin	Poisonous snapping spines
Skunk	An ill-smelling fluid which it ejects
Spiny anteater, porcupine, hedgehog	An armor of spines as a body covering
Tiger, lion	Sharp teeth and claws

Problem 5. How do certain plants and animals capture and kill their prey?

We have now pursued our study far enough to see that the earth is filled with organisms only that other organisms may live. We are familiar with the fact that animals prey upon other animals. Cats catch mice and birds; birds feast on insects and sometimes on fish; owls and hawks swoop down upon other birds and smaller animals, such as rabbits and frogs; snakes swallow many forms of animal life; the more ferocious wild beasts prey upon other forms of animal life, including man. We know, too, that all animal life is sustained, directly or indirectly, by plant life. Animals die and in turn contribute to

THE SQUID'S CHEMICAL PROTECTION

Courtesy *New Wonder World*

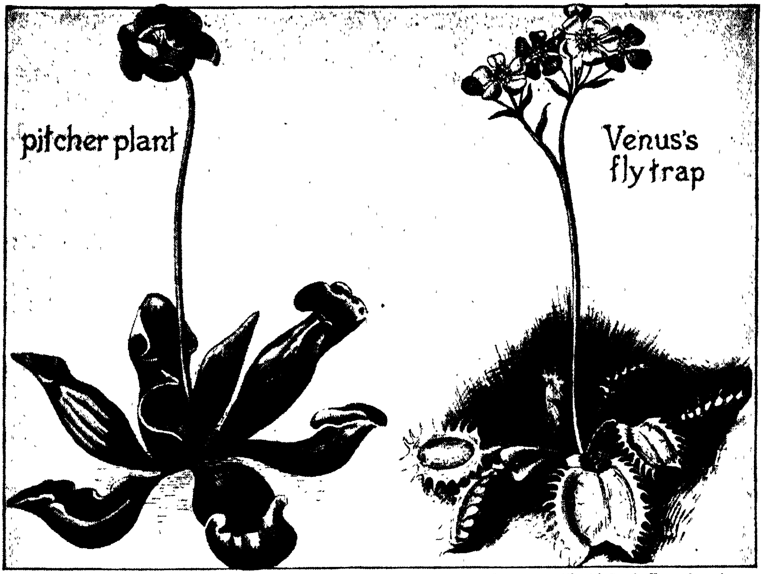
When an enemy approaches, the squid discharges an inky fluid or smoke screen which so darkens the water that it easily gets away from its pursuer.

the existence of plant life by fertilizing the soil. It is thus that the cycle of life goes on. Many of us, however, do not know that plants, too, prey upon other forms of life. We shall learn about some such plants on the following pages.

PLANTS THAT KILL THEIR PREY

If plants could exhibit a feeling of satisfaction, the Venus's flytrap, the sundew, the pitcher plant, and certain other plants would show how they enjoy catching prey. These plants live partly upon the bodies of insects. They live in swampy, boggy places where nitrates are comparatively scarce but where there is an abundance of insects to provide nitrogenous food. Most predaceous plants catch and devour insects, but some even devour such animals as worms, larvae, and small fish. Altogether there are about four hundred kinds of animal-eating plants in the world.

TWO PLANTS THAT EAT INSECTS



Courtesy *World Book Encyclopedia*

How is each of these plants adapted to catch, kill, and eat insects?

Venus's flytrap. In many ways the Venus's flytrap is the most remarkable of all the predaceous plants. It grows in marshy places and is found most abundantly in North and South Carolina. This plant operates on the same principle as a steel trap, snapping shut on an unsuspecting insect. Each leaf is a separate trap. The leaf ends in two lobes that are hinged at the midrib, each of which is fringed with stiff processes like the teeth of a trap for animals. On the upper surface of each lobe are glands that secrete a purplish juice that insects like. Among these glands are tiny hairs that make the plant sensitive. When an insect enters the leaf to satisfy its appetite, it accidentally touches these hairs, the leaf closes, and the marginal teeth interlock, holding the insect a prisoner. (See the illustration on this page.) The leaf then pours an abundant secretion of enzyme on the crushed and smothered victim so that the nitrogenous matter in its body can be digested and absorbed. After absorption has taken place, the leaf opens up.

The whole process of catching and consuming an insect takes many days, and the same leaf is rarely able to digest more than two or three insects before it dies.

Pitchers that are traps — pitcher plants. The sidesaddle plants, as the pitcher plants of America are called, grow in bogs. Their leaves are arranged in circles at the surface of the water. These leaves resemble pitchers with broad, erect lids. Insects are attracted to the leaves by their bright color and by secretions of nectar. When a greedy insect enters a pitcher leaf, it finds itself on a slippery surface of downward pointed hairs that make its return impossible. It tumbles into a fluid at the bottom of the pitcher, where it drowns and decomposes. The manner in which the insect is digested and absorbed is not exactly known. Different species of pitcher plants vary greatly, having pitchers that range from the size of a thimble to the size of a quart measure.

Plants that capture insects by means of sticky tentacles. The sundew, which thrives because of its predaceous habits, grows among the mosses in bogs. It seems to be "inhuman" in the treacherous way in which it ensnares its insect prey. The upper surface of each leaf is covered with about two hundred red glandular hairs or tentacles. The tip of each tentacle secretes a sticky substance that looks like a glistening dewdrop. It is from this appearance that the sundew gets its name. When an insect, attracted by the color and slight fragrance of the sticky substance, touches the tentacles of a leaf, it sticks fast. Then the tentacles curve toward the center of the leaf, rolling the struggling insect along. Finally the leaf has the appearance of a little closed fist. As soon as the insect is securely imprisoned, the tentacles secrete certain acids and an enzyme which digest the nitrogenous matter of its body. After about two days the digestion is complete, the tentacles of the plant unfold, and the leaf trap is set for another unsuspecting victim.

A small Portuguese shrub called *Drosophyllum* (drō′sȯ-fĭl′-ŭm) is covered with sticky tentacles that catch so many insects that it is used by the peasants as fly paper.

KILLERS AMONG THE ANIMALS

In many groups of animals, from the microscopic one-celled Protozoa to the vertebrates, even including man, there are flesh-eating animals. The *Noctiluca* (nŏk′tĭ-lū′kȧ), for example, is a protozoan that makes seas phosphorescent, but is big enough to capture and kill the larvae of certain worms and some of the minute crustaceans. By means of threadlike tentacles equipped with stings, the sea anemones and jellyfish capture and kill rather large animals for food. The starfish feeds on such animals as crabs, oysters, and clams. The sea urchin, an animal similar to the starfish, preys on barnacles.

AN INNOCENT-LOOKING KILLER

Chace-Century

The praying mantis assumes a position suggesting prayer, but it is really a great killer among the insects.

Insects as killers. Many insects are notorious flesh eaters. The dragon fly captures insects on the wing. The larva of the tiger beetle makes a burrow and uses its head as a treacherous trapdoor. The praying mantis (măn′tĭs) stands quietly in a half-upright position, with bowed head and folded front legs, awaiting a chance to capture and devour insect victims. The female of one species of praying mantis does not hesitate to devour her own mate.

With few exceptions, the scorpions and spiders are predaceous and undoubtedly destroy many noxious insects. Centipedes prey upon earthworms, cockroaches, and other insects. The large centipedes of the Southwest often kill mice.

Mollusks as killers. Among the better-known killers of the mollusk group are the octopus and the cuttlefish. Long tentacles equipped with suckers enable these animals to catch and hold their prey. Moreover, they are equipped with two highly developed eyes that enable them to see their prey from a considerable distance.

Vertebrates as killers. Fish are important as destroyers of aquatic insects and other small organisms. Sharks are noted as dangerous to man and beast. Toads are fond of slugs and insects. Among the reptiles, snakes, crocodiles, and alligators are the most widely known as flesh eaters. The boa constrictor attains a length of twelve to fourteen feet. Its prey includes such large animals as tapirs and young deer. The huge boa kills by winding itself around the body of its victim and then drawing its coils together, thus crushing the animal into a lifeless mass. The serpent then covers the body of the victim with saliva to make it slippery enough to be swallowed. A poisonous snake stabs its victim with poison fangs instead

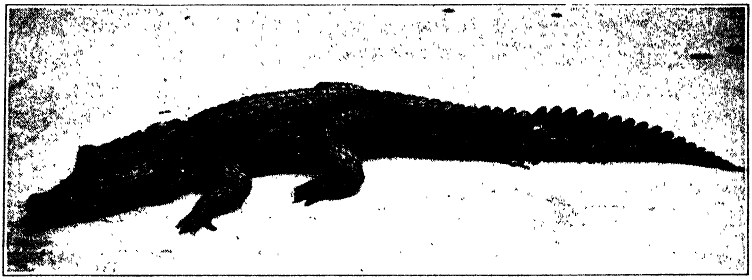
ONE FLESH-EATING ANIMAL MAKING AN END OF ANOTHER

Lynwood M. Chace

This picture shows a garter snake consuming a salamander. The salamander, like the snake, is a flesh-eating animal and has consumed many living things itself.

of biting it. When a mouse or rabbit comes close enough, the snake darts forward, opens its jaws, and thrusts its fangs into the animal's body. This deed is done so quickly that the

A MAN-KILLING REPTILE—THE CROCODILE



Courtesy American Museum of Natural History

Crocodiles are the largest reptiles to be found anywhere in the world. This picture shows a species of broad-nosed crocodile found on the continent of Africa.

ANOTHER FLESH-EATING REPTILE

Courtesy New York Zoölogical Society

The giant tortoise is the largest that exists, sometimes weighing as much as six hundred pounds.

eye cannot follow it. The victim becomes paralyzed, and, in a minute or two, succumbs to the poison. In India the man-eating crocodile levies almost as high a toll on human life as does the tiger or the cobra. Alligators eat mammals, birds, and fish. They even kill dogs by grasping them in their huge jaws and holding them under the water until drowned. As may be expected, they swallow such victims at one gulp. Among the carnivorous birds, the eagle, owl, hawk, and shrike are best known for their flesh-eating habits.

The flesh-eating mammals. Some of the well-known representatives of the flesh-eating mammals are the tiger, lion, wolf, bear, raccoon, dog, cat, and seal. These killers are provided with sharp teeth and claws by means of which they capture, mangle, and devour their victims. Lambs, pigs, and calves form a part of the menu of the black bear, which

THE OTTER WITH ITS DINNER

Courtesy *World Book Encyclopedia*

Fish are the favorite item in the bill of fare of the otter.

was once found over the greater part of the United States. The lion, sometimes called the "king of beasts," and the tiger, which exceeds even the lion in strength and ferocity, both prey upon the other beasts of the jungle.

THE BALANCE OF NATURE

Charles Darwin, the great scientist and naturalist, made it clear that all living organisms are so interdependent that neither beast nor plant can live unto itself alone. All animal life, including our own, is dependent on plants for food. The carnivorous animal eats flesh, but the flesh may be that of an animal that feeds on the juicy leaves of plants. The balanced aquarium illustrates the balance that nature maintains in the perpetuation of life.

When man interferes with the balance of nature, the results may be far-reaching and often difficult to correct, as in the case of taking rabbits to the continent of Australia. A number of years ago the German carp was introduced into the streams and lakes of the Middle West. In the clear streams of its native habitat this large fish is valuable for food. In its new home, however, it found streams and lakes with muddy bottoms and swallowed muck with the vegetation on which it fed. Its flesh therefore took on an unpleasant muddy

taste. In the spring great schools of carp came up the streams to spawn, rooting up the bottoms. In a few years most of the aquatic vegetation was killed, and other game fish disappeared with the plants that had given them food and hiding places. Thus the whole balance of nature was upset by the introduction of one species of fish. Efforts made to exterminate the carp have now reduced its numbers so that it is no longer a menace.

The introduction of any new insect pest is almost certain to upset the balance of nature. In their original home most insects have natural enemies which keep them under control. When they enter a new environment from which their enemies are absent, they multiply very rapidly. Thus the cotton boll weevil, spreading from Mexico, threatened to wreck the cotton industry of the South; and the San Jose scale was a serious menace to the fruit grower until the ladybug was introduced to combat it.

Many other instances of overproduction of certain forms of life might be cited, such as the overproduction of barberry, on which wheat rust develops. Those already given, however, are sufficient to show how easily the balance of nature may be disturbed. To help bring about an adjustment when the balance has been disturbed, man often makes laws to protect certain desirable forms of life or to bring about greater destruction of undesirable forms. Both the United States and Canada have passed laws designed to protect certain species of wild life; and some states offer bounties for the destruction of undesirable species.

The balance of nature is not the same the world over but varies in every region and life zone according to environmental conditions, such as soil, climate, and topography. Each life zone has its own particular plants and animals that are suited to its conditions and that can live together, all finding sufficient food, often preying upon, but never completely destroying, one another. Thus in the great scheme of life, each living organism has its purpose and its place in the world. Sometimes the balance is temporarily disturbed, but only briefly, because nature steps in and puts everything in order again.

SUGGESTED ACTIVITIES

I. Self-Organization Summary

A. Food Cycles of Green Plants
   1. Trace the balancing processes that occur between plants and animals in an aquarium.

B. Partnerships in the Plant and Animal Kingdoms
   1. What mutual benefits are obtained by each organism in the following partnerships?
      a. The sea anemone and hermit crab
      b. Aphids and ants
      c. Nitrogen-fixing bacteria and clover plants

C. Plant and Animal Parasites and Saprophytes
   1. Prepare a three-column chart as follows: In the first column list the plant and animal parasites discussed in this unit; in the second column place the names of the respective host or hosts; in the third column state the injury done to the host.
   2. Trace the life cycle of the wheat rust.

D. Survival Adaptations—Mimicry and Defenses
   1. List ten examples of protective coloration in animals.
   2. Explain the principle of counter-shading.
   3. Give three examples of mimicry of body form.
   4. List ten animals that have distinctive means of defense and tell what the defenses are.

E. Predaceous Plants and Animals
   1. Describe the structure and habits of three insect-eating plants.
   2. Name flesh-eating animals in a sequence, beginning with the protozoans and going to the higher forms.
   3. Explain nature's scheme for keeping her organisms in balance.

II. Laboratory Study

A. Prepare a balanced aquarium for study in connection with Problem 1 of this unit.

B. Bring in several specimens of plants and animals for a class collection. Then, as a class project, sort the specimens into such groups as parasites, saprophytes, partnerships, and predaceous organisms.

C. Make a table showing the food cycles of green plants.
D. Make a table listing all of the plant and animal adaptations you have seen.

III. Display Posters

It may have already occurred to you that this unit affords many opportunities for making valuable display posters illustrating protective mimicry, partnership relations, and predaceous plants and animals. For your posters you may use actual photographs, pictures taken from nature magazines, or water-color drawings if you are able to make them.

IV. Field Trips

A. Go to the fields or woods to observe examples of:
  1. Protective mimicry
  2. Parasitic and saprophytic plants
  3. Partnership relations among plants and amimals
B. Visit a zoo or a natural history museum, if there is one in your community, and study the adaptations that animals have made for mutual helpfulness.

V. Special Reports

The following is a list of suggested topics that have been wholly omitted or only partly treated in this unit:
A. How to construct and maintain a balanced aquarium
B. Rotation of crops
C. Other strange partnership relations
D. The crocodile's "toothbrush"—the zic-zac
E. Appendage adaptations in animals
F. Integument adaptations in animals

REFERENCES[1]

1. Clark, Austin H. *Nature Narratives.*
  a. An insect partnership, pp. 100–103
  b. Animal-eating plants, pp. 130–133
2. Eifrig, C. W. G. *Our Great Outdoors—Reptiles, Amphibians, and Fishes.*
  a. Carnivorous animals—snakes, crocodiles, alligators, etc., pp. 3–77

[1]The pages listed here are those found in the editions indicated in the alphabetical list of references given at the end of this book.

3. Shipley, Sir Arthur E. *Life.*
   a. Feeding, chap. IV
   b. The nitrogen cycle, chap. VI
4. *Book of Popular Science, The.*
   a. The defenses of plants, Vol. 8, pp. 2613–2621
   b. Warriors of the ocean (predaceous animals), Vol. 13, pp. 4255–4265
5. *Compton's Pictured Encyclopedia*
   a. Protective coloration, Vol. 11, pp. 353–356
   b. Dependent plants—rusts and smuts, Vol. 12, pp. 199–201
6. *New Wonder World, The.*
   a. Queer ways of getting a living, Vol. 10, pp. 136–143
   b. Stealing a living, Vol. 10, pp. 55–57
7. *World Book Encyclopedia, The.*
   a. Protective coloration, pp. 5850–5851
   b. Plant and animal parasites, pp. 5363–5365

VISUAL AIDS

FILMS (16 mm.)

A. Erpi Picture Consultants, Inc., 250 West 57th Street, New York City.
   1. How Nature Protects Animals. 1 reel, sound, $50.00.
      Shows various ways in which animals conceal themselves either for purposes of defense or for purposes of securing food
   2. Plant Traps. 1 reel, sound, $50.00.
      Shows how predaceous plants trap and kill their prey
   3. Dodder. 1 reel, sound, $50.00.
      Traces the entire life history of this important flowering parasite

B. Bell and Howell Company, Chicago, Illinois.
   1. Killers. 1 reel, sound, $1.50 per day.
      Illustrates activities of such predaceous animals as the mantis, wasp, spider, and scorpion

C. Indiana University, Extension Division, Bloomington, Indiana.
   1. Animal Camouflage. 1 reel, silent, $1.00 per day.

D. Walter O. Gutlohn, Inc., 35 West 45th Street, New York City.
   1. Killing the Killer. 1 reel, sound, $1.50 per day.
      Pictures a fight between a mongoose and cobra

UNIT TEN

HOW PLANTS AND ANIMALS BEHAVE

SUGGESTIONS TO THE TEACHER

This unit deals with the common forms of behavior that may be observed in plants and animals. Most people think of plants as static, or at least as unresponsive, organisms. Animal responses are usually more dynamic, and consequently more evident than those of plants. Then, too, in most cases animal responses are more complicated and are executed with more rapidity than are plant responses. The student should come to realize, however, that both plants and animals react to stimuli in their environment, and he should learn about some of the more important of the responses. The last problem of the unit is concerned with the human mode of behavior, including reflexes, habits, instincts, and intelligence. From a study of these topics it will be apparent why man is superior to all other forms of life. It is not expected, of course, that the student at this stage go into a technical or complicated study of psychology, but that he merely come to understand some of the more simple types of behavior, especially those related to the physical side of life.

OBJECTIVES

I. Facts and principles

A. To realize that plants as well as animals are sensitive to their surroundings and respond to stimuli by behavior which helps them to survive and reproduce themselves

B. To learn about some of the common forms of behavior in plants, such as responses to gravity, light, water, certain chemical substances, temperature, and contact

C. To learn about some of the common forms of behavior in animals, such as simple reflexes, instincts, and acts of intelligence

II. Attitudes

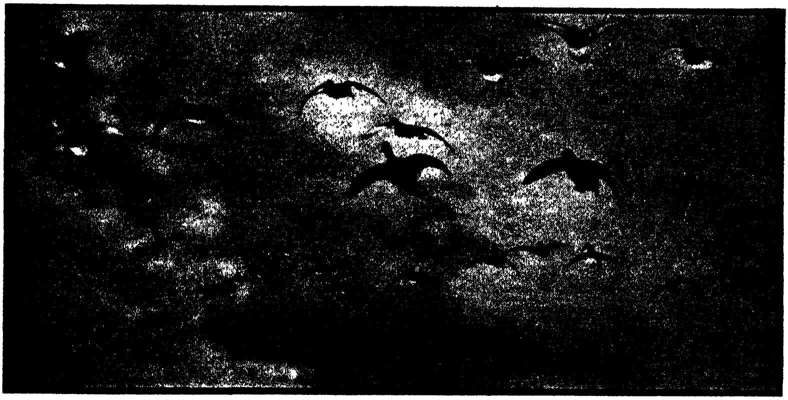
A. To cultivate an interest in the behavior of plants and animals and a disposition to inquire into its significance

B. To realize that mental life is an essential part of our existence

UNIT TEN

HOW PLANTS AND ANIMALS BEHAVE

WILD DUCKS MIGRATING NORTHWARD IN SPRING



Century Photos

Almost before the ice is gone from northern lakes, the ducks speed northward in great flocks for their nesting season. The migratory instinct of birds is one of the strongest urges in the animal kingdom, and one that man has not been able to explain.

HOW DO THEY KNOW?

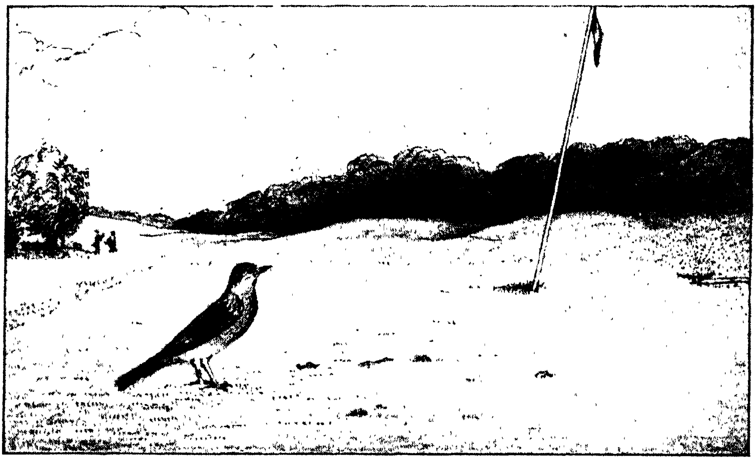
PREVIEW

Strange behavior on the golf course.[1] Did it ever occur to you that mere worms might interfere with one of America's greatest sports? This occasionally happens when earthworms infest the putting greens of a golf course. These little creatures, as you know, live in the ground, but come to the surface and deposit little heaps of mud or "castings" around the openings of their burrows. Such deposits here and there on the putting greens seriously impair the accuracy of a golfer, for the balls are deflected and do not go where he intends they should.

[1]The facts in this story were reported by "Andy" Anderson, golf professional at Highland Springs Golf Club, Akron, Ohio.

The caretaker of a certain golf course put up a desperate fight against the earthworms. Every day he rolled the greens so as to flatten down the many little mounds on the surface. The next day, however, he would find just as many mounds as

HOW PESKY EARTHWORMS SPOIL A GAME OF GOLF



Why must the greens on a golf course be kept very smooth? How would little mounds of dirt, as shown in the picture above, greatly interfere with a golfer's sport?

there were before, for within twenty-four hours the pesky little worms would come to the surface and leave their deposits of mud. Greens, of course, must always be sprinkled to keep the grass fresh; but the caretaker discovered that, every time he sprinkled, more earthworms would come to the surface than at any other time. This was because earthworms breathe through their skins and would have eventually drowned in their water-soaked burrows had they not come to the surface for air. The caretaker noticed that immediately after each sprinkling robins, which are especially fond of earthworms, usually alighted on the greens to get a good meal. They seemed to know just when to come.

Perplexed by this situation, the caretaker now sprinkled poison on the greens to get rid of the earthworms. Then he noted an interesting behavior on the part of the robins. They

seemed to know that something had happened, picked slightly at the poisoned worms, and left without eating. Even more striking was the fact that, from then on, they showed little interest in the worms. Now and then, they alighted upon the greens, inspected the worms, and left. Finally they stayed away from the greens and ignored the worms entirely.

Can you explain the forms of behavior described in the foregoing story? How did the robins know that something had happened the first day the poison was applied? How did they know that the earthworms were "dangerous" when they came to the greens later on? How did the earthworms know that they would suffocate unless they came to the surface whenever the greens were sprinkled? What mechanism enabled these lowly creatures "to respond" to their environment? Can you explain why many other living organisms, including plants, behave as they do? The following problems will help you to answer some of these questions.

PROBLEMS

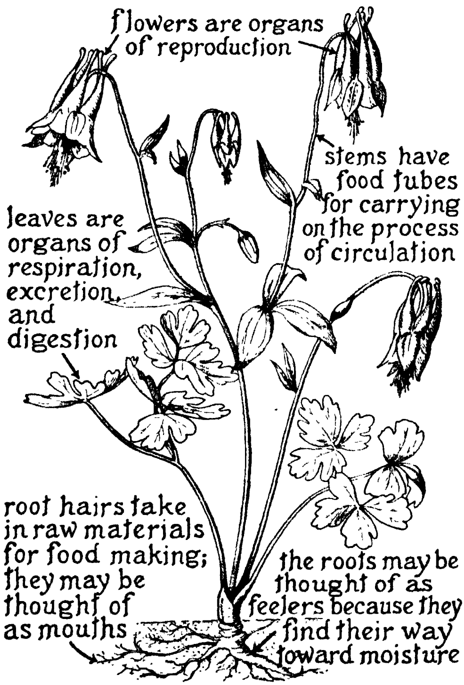
1. **How does the behavior of plants indicate that they respond to their environment?**
2. **How does the behavior of animals indicate that their response to stimuli is controlled by a nervous mechanism?**
3. **What types of nervous mechanisms are found in various animals?**
4. **How does the nervous system in the human body function?**

Problem 1. How does the behavior of plants indicate that they respond to their environment?

A force or substance that acts upon an organism of any kind is called a *stimulus*. The reaction of an organism to a stimulus is known as a *response*. All forms of life are subject to responses because the protoplasm, or living material, of which they are composed is sensitive to certain stimuli.

Plants as living organisms. As we consider the question of behavior in plants, we must remember that they are *alive* just as animals are alive. They breathe and consume food. Also, they react to various conditions in their environment, such as light, heat, and moisture. If certain salts are missing from the water solutions taken into their bodies or if there is too much or too little water in the soil, they sicken and die. If, however, the supply of mineral salts is well balanced and the proper conditions of light and temperature are present, they continue strong and healthy. In other words, they lead normal lives.

A LIVING PLANT



This drawing shows how the parts of a plant are adapted to carry on life processes. Note that many processes are similar to those performed by animals.

Some people seem to feel that plants are uninteresting; that they lead very dull lives. When we come to know plants well, however, we find that they have many exciting adventures, tragedies, and triumphs. Then, too, all kinds of plants, from the lowly fungi to the highest seed plants, must struggle against many kinds of enemies.

Comparing plants and animals. In attempting to point out differences between plants and animals, many people make the mistake of saying that plants show no movement and make no responses to outside stimuli. The truth of the matter is quite the contrary. Plants and animals differ greatly in appearance,

it is true, but in their fundamental functions they have certain similarities. Both are made of cells that form tissues and organs. The structure of their cells, however, explains the real difference. Plant cells have very hard walls, but animal cells do not. The cells of green plants contain chlorophyll, but those of animals have nothing of this kind. Finally, plants and animals differ in the organs they use to carry on the various processes of life.

By comparing their methods of feeding, movement, sense perception, and other activities, we shall better understand how plants and animals differ in their reactions to the various stimuli in their surroundings. The following tabulation indicates why certain differences may be expected.

In Plants	*In Animals*
Reactions to stimuli usually very slow	Reactions to stimuli usually quite rapid
No nervous system to control behavior	Nervous system in all but the lowest forms
No muscular system to produce motion	Muscular system in all but the lowest forms

THE MECHANICAL RESPONSES OF LIVING ORGANISMS—TROPISMS

The word *tropism* (trō′pĭz'm), which is used extensively throughout this discussion, is derived from the Latin word *tropus*, meaning "turn." It refers to the simple reaction of plants and lower forms of animals when they are acted upon by outside influence, such as light or heat. The cells of such forms of life receive stimuli and accumulate them until the combination is strong enough to bring about a response. In other words, the cells in a certain part of the organism react together. Most animals, on the other hand, react through certain organs, such as the ears and the eyes. The principal forms of tropisms are as follows:

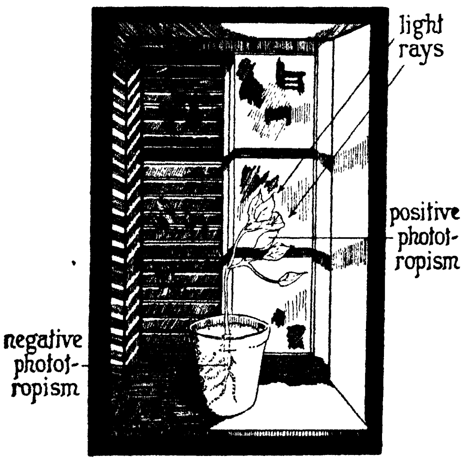
1 *Phototropism* (fȯ-tŏt′rȯ-pĭz'm)—the turning toward light or away from it

2 *Hydrotropism* (hī-drŏt′rȯ-pĭz'm)—the turning of roots toward, or in some cases away from, water

3. *Geotropism* (jē-ŏt′rō-pĭz'm)—the turning toward, or away from, the center of the earth
4. *Thermotropism* (thẽr-mŏt′rō-pĭz'm)—the turning toward, or away from, heat
5. *Thigmotropism* (thĭg-mŏt′rō-pĭz'm)—the turning toward, or away from, contact
6. *Chemotropism* (kē-mŏt′rō-pĭz'm)—the turning toward, or away from, chemicals

How plants react to light—phototropism. The upper parts of plants, the stems and leaves, are said to be *positively phototropic;* that is, they turn toward light. The turning is due to the effect of sunlight upon the protoplasm of the cells. The roots turn away from light and are therefore *negatively phototropic.* A simple little experiment at home or in the classroom will illustrate both these tropisms. A glass tumbler should be filled three-fourths full of water containing all the minerals necessary for the growth of a plant. Some cotton should next be placed on the surface of the water. Then if a mustard seed is put on the moist cotton, it will develop into a plant just as if it were growing in soil. As the mustard grows, the tumbler should be placed at some distance from a window and the movements of the parts noted. It will be found that the stem will lean toward the light and the leaves will turn their surfaces to catch more of the light. Thus they will be positively phototropic. The roots which have grown downward will turn away from the light and be negatively phototropic.

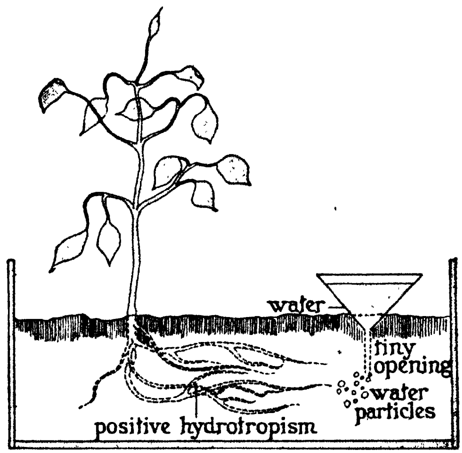
A PLANT RESPONDING TO LIGHT



The turning of stem and leaves toward the light is known as positive phototropism.

"Water-turning" in plants—hydrotropism. The roots of most plants are exceedingly sensitive to moisture. Water in the ground passes from wet places to drier places by a process called *capillarity* (kăp′ĭ-lăr′ĭ-tĭ). The moisture that reaches the roots provides a favorable environment for their growth. Consequently they tend to grow in the direction of the source of the water. It has been said that roots seem to have "eyes" when they go in "search" of water. Of course the roots do not actually seek the water, but they turn toward it only when some of it reaches them and they feel its effects.

A PLANT RESPONDING TO WATER

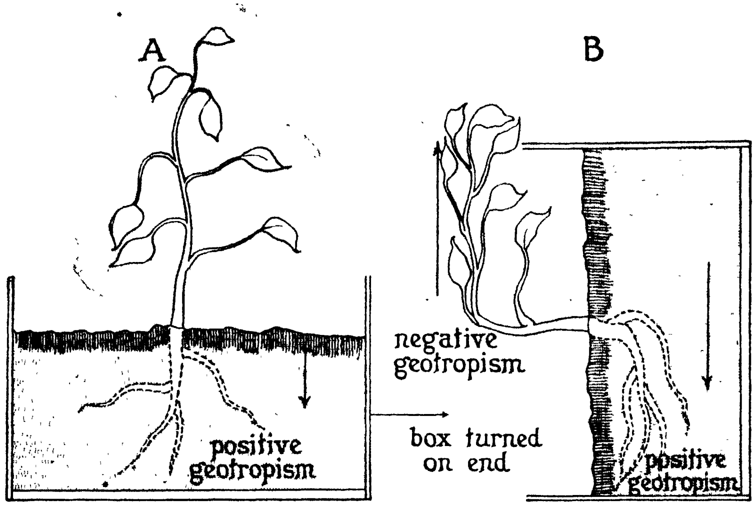


The turning of roots toward the water supply is known as hydrotropism.

This hydrotropism of roots may be observed especially where willows or poplar trees are growing near tile drains and sewers, for their "thirsty" roots often completely clog the pipes. Hydrotropism may also be observed by means of a simple experiment. A small plant should be placed near one end of a shallow box partly filled with soil. A stem or tubular end of a funnel partially filled with water should be placed in the soil near the other end of the box. The water will then gradually pass out of the funnel into the soil. Examination of the roots of the plant after a few days will show a greater growth in the direction of the water than in any other direction. This illustrates one reason why roots naturally grow downward in the soil.

The downward pull of gravity—geotropism. It is a peculiar fact that, when a plant which has been growing in a vertical position is placed in a horizontal position, the roots will again bend downward and the stem will point upward. Such a

A PLANT RESPONDING TO GRAVITY



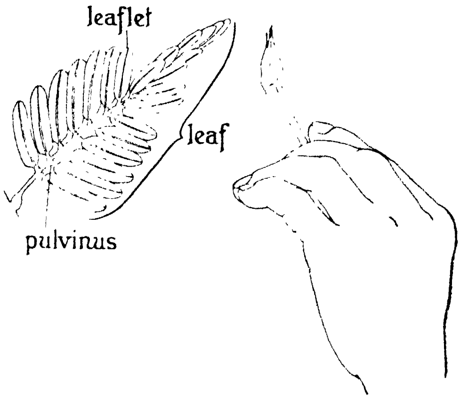
The plant in the box at the left (drawing A) shows how plants normally react to the force of gravity. The plant in the box on end at the right (drawing B) shows how plants continue to react even when their normal positions are greatly changed.

tendency of roots to grow downward and of stems to grow upward is called *geotropism* and seems to be produced by gravity. If a bean seed is placed in a box containing wet sawdust and is allowed to develop, the stem will grow up into the air and the root will grow downward. Then if the box is placed on end, the root will again bend downward and the stem will turn upward. Such an upward growth represents a *negative geotropic* response by the plant. The downward growth of the root represents a *positive geotropic* response.

How plants react to heat—thermotropism. Certain plants, such as a few species of *Mimosa,* respond so quickly and definitely to disturbances that they have been popularly called *sensitive plants.* Each leaf of the Mimosa is composed of a number of small leaflets. These leaflets are arranged on opposite sides of a *midrib* (big central rib) and fold together when an object comes into contact with them. If a lighted match, for instance, is touched to the tip of the leaf, a series

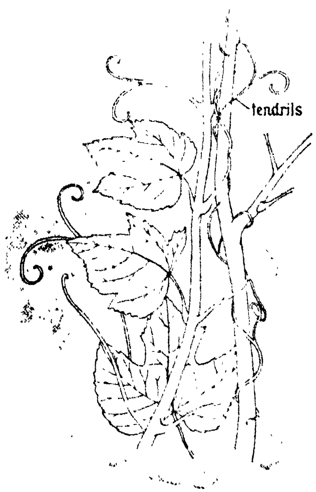
of movements results. The pair of leaflets nearest the burned point immediately folds up. In an instant the next pair of leaflets does likewise. This folding-up process continues from the tip to the base of the leaf. In less than a minute the whole leaf will be folded up. Then it drops, owing to a crumpling of the *pulvinus* (pŭl-vī′nŭs), which is a cushion-like enlargement of the stalk of the leaf at the point where it is attached to the stem. The burning of the tip of the leaf produces an injury and starts an activity that passes downward from cell to cell along the midrib of the leaf to the stem. This action, known as *thermotropism,* causes the pulvinus of each leaflet to collapse and finally the pulvinus of the whole leaf to collapse.

A PLANT RESPONDING TO THE HEAT OF A MATCH



This drawing shows what happens when a lighted match is brought close to a tender Mimosa leaf. The little leaflets fold up in pairs along the midrib. How can you explain this action?

A PLANT RESPONDING TO CONTACT



The tendrils of plants are sensitive to touch or contact. This reaction is called thigmotropism. The plants use the tendrils for climbing.

How plants react to contact—thigmotropism. The leaves of Mimosa respond to contact just as they do to heat. The response of parts of a plant to the stimulus of contact is called *thigmotropism.* Such plants as the grape, squash, and garden pea produce *tendrils*—

slender, threadlike organs which are sensitive to contact. Some of these tendrils wrap themselves about near-by objects and enable the plants to climb. Other tendrils seem to serve as feelers and are very sensitive. Those of the one-seeded bur cucumber are so sensitive, for example, that they begin to curve whenever they come into contact with an object.

How plants react to chemical stimuli—chemotropism. To perform their work, roots need air and turn toward loose aërated soil provided it contains the necessary mineral substances. Since these substances are not uniformly distributed, they turn toward that part of the soil where the proper stimulus is supplied. Such a tendency to react to chemical substances is called *chemotropism.* This form of tropism may also be illustrated by the tubes that pollen grains send out in the process of germination. These tubes are attracted by food substances in the pistil and continue to grow until they reach the ovary and thus make germination possible.

Problem 2. How does the behavior of animals indicate that their response to stimuli is controlled by a nervous mechanism?

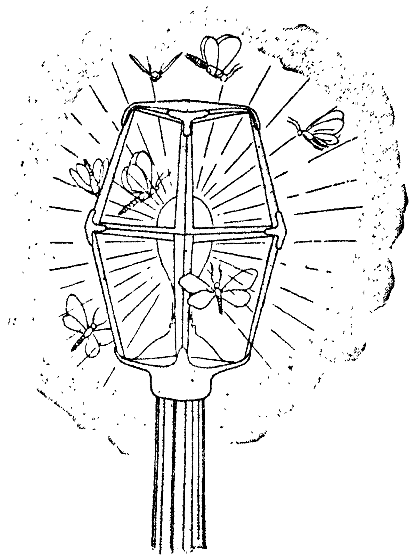
ANIMAL BEHAVIOR NOT INVOLVING INTELLIGENCE

Tropisms in animals. The term *tropism* is seldom used in describing the behavior of higher animals, since it refers to mere mechanical reactions. It explains fully, however, the reactions of such simple forms as the amoeba to conditions in the environment. The amoeba moves away from strong light, and may be said to be negatively phototropic. The ordinary clothes moth likewise avoids the light. Insects that fly around street lights at night are said to be positively phototropic because they move toward the light.

Many insects are attracted by strong odors. Some species of fish are attracted or repelled by the odors of various substances in water. Even the tiny Protozoa react to sudden changes in the temperature, moving to a place in the water where the temperature is more nearly uniform.

A simple type of nervous response—reflex action. It is surprising to know that much of the activity of organisms is believed by biologists and psychologists to be more or less mechanical behavior. All animals, from the Protozoa to the vertebrates, including man, show simple types of mechanical behavior that are called *reflexes*. There seems to be no sharp distinction between tropisms and reflexes. The main difference is probably that the simple mechanical behavior of a larger part of an organism is called a tropism, whereas the slightly more complicated behavior of a smaller part of an organism is called a reflex. Many simple responses, therefore, may be classed as either tropisms or reflexes.

INSECTS RESPONDING TO LIGHT



Animals, like plants, show certain tropistic movements. The insects flying toward the street light illustrate positive phototropism.

The chief characteristics of simple reflexes are as follows: (1) the stimulus causes an immediate response; (2) the response is not acquired or learned; (3) the response is local and involves only a certain part of an organism.

If a person unexpectedly brings his hand into contact with an object that produces pain, he will instantly jerk it away whether he be awake or asleep. The response is completed without any intervention of consciousness. This is an illustration of reflex action. The same type of response is made by other animals. The earthworm, for instance, quickly pulls its head into its burrow when it is touched.

The next question to answer is just how reflex action takes place. One-celled animals, such as the Paramecium, do not

have any special part of the cell fitted to receive stimuli. The many-celled animals, however, have certain organs specially fitted to receive such stimuli as touch, light, and sound. When the sensory nerve cells of an organ are stimulated, a message is carried inward to certain controlling nerve cells in the central part of the body. These cells then send a message to a muscle so as to bring about involuntary action. The movement may be either toward or away from the source of the stimulus, depending upon the kind. Thus an animal may move toward food or away from harm.

Fixed ways of animal behavior—instincts. Many of the lower animals have a large part of their behavior fixed by an inherited nervous system in which a large number of reflexes are rather firmly established. When such animals are placed in definite situations, there is usually only one way for them to respond. This is because of the inherited tendency to respond according to a fixed pattern. Such a tendency is called an *instinct*. It will be seen that an animal, such as a worm or an insect, that reacts almost entirely according to inborn automatic responses (simple reflexes) has very little to learn. This does not mean that instinctive acts may never be varied, but that they may be changed only with great difficulty.

Results of instinctive behavior. Since instinctive responses are inherited and not learned, an animal may perform them perfectly the first time. Thus a cat may catch a mouse as readily the first time it sees one as it will after catching a great many mice. It also follows that one member of a species is usually able to perform an instinctive act as well as any other member. For example, without any training, one cat is usually able to catch mice about as well as another.

Sometimes we marvel at what an animal is able to do without ever having been taught. The oriole, for instance, weaves its wonderful nest without ever taking a single nest-building lesson. Furthermore, in construction its nest will be exactly like those of all other orioles. Shortly after a chick is hatched from an incubator it begins to walk or run about in search of food. It scratches the ground and pecks as the older chickens do.

INSTINCTIVE BEHAVIOR IN CHICKENS

H. Armstrong Roberts

Chicks a day or two old are much better able to care for themselves than are the young of most birds. They begin to walk about shortly after they hatch.

Instinctive acts usually result in some advantage to an animal, such as feeding, mating, and finding protection. However, when instinctive behavior is harmful, it is always carried out with the same precision as when it is helpful. For example, the instinctive tendency of moths and certain other insects to fly toward a light may lead them into a flame. Furthermore, the tendency to perform instinctive acts seems to persist in most animals long after the necessity for performing them has ceased to exist. The ancestors of the domestic dog turned around several times before lying down to rest, to make sure that no enemies were near. Today a dog almost always goes through the same turning performance even though it is preparing to lie down on a rug in front of the fireplace.

Although instincts enable many animals to do things without going through a long process of learning, we should not envy them. Our superiority lies in the fact that we have ability to learn and do not have to follow set patterns of behavior. We learn through experience how we should behave. Thus it is that we develop the powers that make us superior to all other animals.

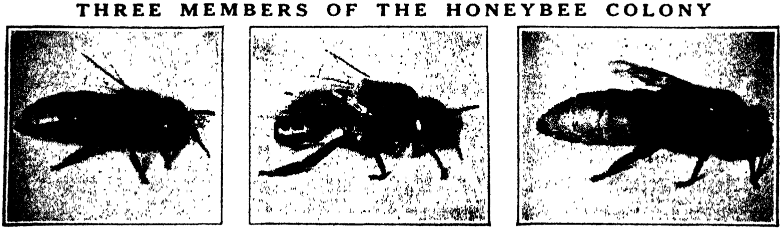
ORGANIZED SOCIAL LIFE AMONG THE INSECTS

Few animals other than man are social in their behavior. We see birds gathering in flocks, fish swimming in schools, and certain mammals traveling in herds, but they never lead truly social lives. By social life we mean that the members of a group build a common home, gather food for the benefit of all the members, and unite in providing protection against enemies and other common dangers.

The Busy Little Bees

Bees truly social creatures. Perhaps no better example of definitely organized social behavior may be found than that of bees. These little creatures possess everything in common and perform all their work for the common good. They

THREE MEMBERS OF THE HONEYBEE COLONY



Courtesy A. I. Root Company

These illustrations show, from left to right, a worker, a drone, and a queen.

maintain a very democratic community in which the citizens (workers) work together, the kings (drones) are powerless, and the queen is a respected leader.

The castes of bee land. The various members of the bee colony are divided into castes known as workers, drones, and

queens. The *workers* are females specially fitted physically to carry on the unceasing labors of the colony. They are by far the most numerous members of the group, sometimes numbering as high as fifty thousand in a single colony.

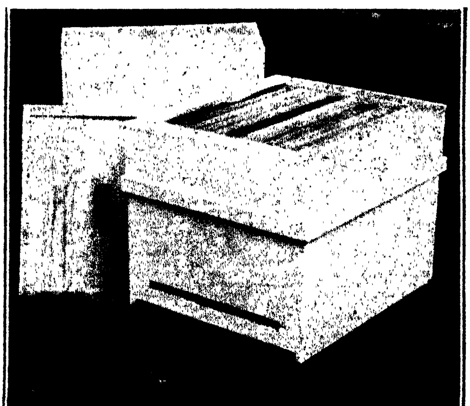
The *drones* are the male bees of a colony, and they may be distinguished from the workers by their broad, blunt bodies. They are heavier than the workers and have strong wings that extend the full length of their bodies. A colony usually contains about four hundred drones.

The body of the *queen*, or mother of the colony, is longer, more slender, and more tapering than the bodies of the workers and drones. She may also be distinguished by the golden color of the lower part of her body. There is usually only one queen in a colony.

A Visit to the Workshop of Bees

Where the bees live. Honeybees build their home in such places as hollow trees, old stumps, and abandoned chimneys. They have been known to go through holes in weatherboards and make their nest in the side of a house. Let us now see how their home is built.

THE HOME OF A SWARM OF BEES



Courtesy A. I. Root Company

Bees have adjusted themselves to man-made hives such as shown above. They even store honey in racks that have been specially prepared for them.

The workers eat large quantities of honey, after which a liquid is secreted on the undersurface of their abdomens. This secretion soon hardens into thin plates of wax which are used in building the many cells of the honeycomb. These cells are uniformly six-sided and fit together in such a way as to provide a maximum of

space for holding liquid contents. Some of the cells, however, are used as nurseries for the young. In the manufacture of their honeycomb homes, honeybees display architectural skill unsurpassed by any other animal except man.

The royal mother and her duties. The queen grows in one of the large wax cells along the edges of the comb. When in the larva stage, she is fed "royal jelly," a rich food prepared by the workers. This food enables her to develop into a full-grown bee within a very few days after she has hatched from an egg. The new queen is immediately surrounded by a number of workers that protect her from the attacks of her predecessor. The only choice left for the old queen is to get out of the way and leave the new queen in charge. It may be said that the old queen abdicates, for she leaves to set up a new colony, taking with her all the subjects that remain loyal.

WANTED! A NEW HOME

Lynwood M. Chace

When bees swarm, they follow the deposed queen from the hive as she sets out to find a new home. They sometimes fly several miles before they settle in a great cluster on the limb of a tree or other convenient place.

In a few days the new queen leaves the hive in search of a mate. The drones fly after her, but drop out one by one as

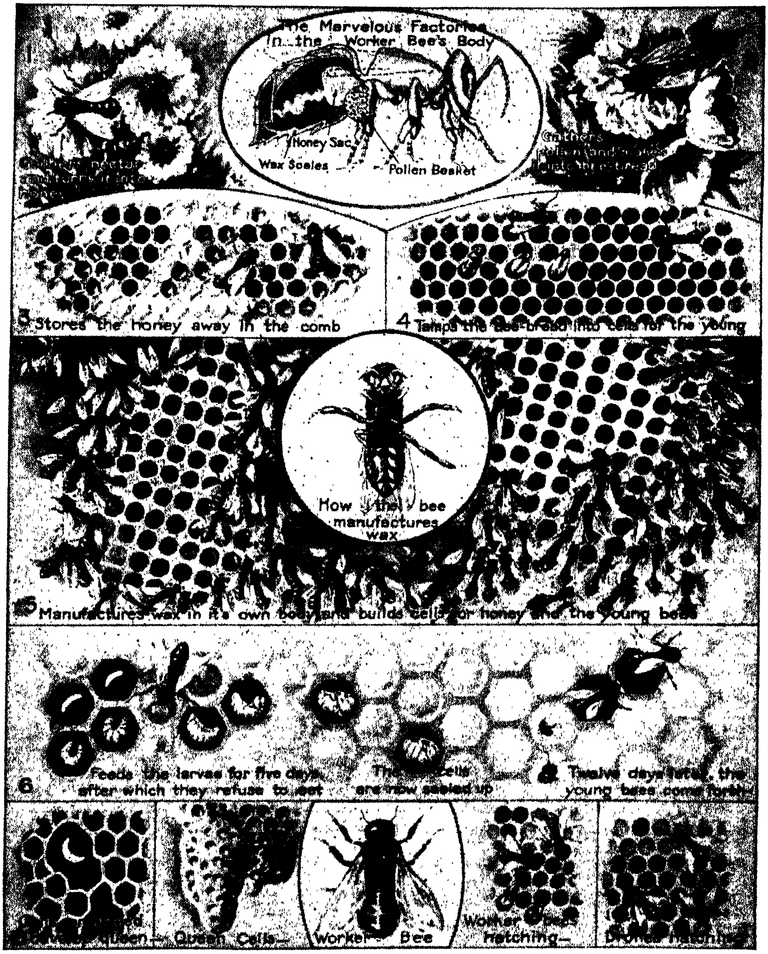
she flies far and high into the air. The flight continues until only one drone is left; then the two mate in mid-air, and the queen returns to the hive. Here she stays until she, too, is driven away. Her time is largely spent in laying eggs, of which when the honey season is on she is capable of producing as many as three thousand in a single day. However, when the flowers are almost gone, she lays a smaller number. A queen may live for several years.

The life of the unfortunate drone. The only unfortunate member of the whole bee colony is the drone. He hatches from an unfertilized egg of the queen, and is unfitted for living with such industrious insects as the workers. Since he has no pollen baskets on his legs, and his tongue is short, he cannot gather pollen or nectar, and must be fed by the workers. Furthermore, he has no sting with which to protect himself from his enemies. The only function of a drone is to mate with the queen, after which he immediately dies. On the other hand, if he does not mate and returns to the hive, he will be driven away or stung to death by the workers. Thus in either case he is doomed to certain death.

The real workers of the colony. From the time these "busy-bodies" mature until they work themselves to death, their short lives are filled with duties. The remarkable fact is that this applies to all and that not one may be said to shirk. The first duty of a worker after maturing is to serve as a nurse to the little bee grubs or larvae. She must assist in house-cleaning, for sanitation seems to be a watchword of the bees. This work involves the removal of dead bodies or foreign particles from the hive. She must also help ventilate the hive by fanning the air with her wings. Since the hive must be protected from the attacks of robber bees, birds, snakes, and other animals, she must take her turn in guarding the entrance. She must help in building cells of the honeycomb.

The most important duty of a worker, of course, is that of gathering pollen and nectar. She must make thousands of trips from the hive to distant flowers in search of food for the other members of the colony. The baskets on her hind legs

THE BUSY BEE AT WORK



Courtesy of and © by *Compton's Pictured Encyclopedia*

This picture shows a worker engaged in some of her many activities. During the busy season she may work so hard that she dies within the brief span of three weeks.

become filled with pollen, which she carries back to the hive, scrapes into the cells, and tamps down with her head. On her trips from flower to flower she swallows nectar, which she carries back to the hive in her honey stomach. A chemical action

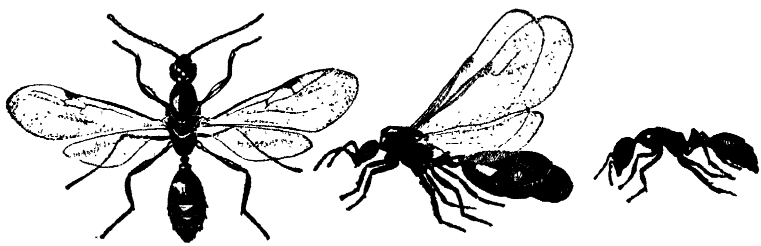
within her stomach changes the nectar to honey, after which it is regurgitated into the cells of the comb. Other bees fan the nectar until much of the water is evaporated. When a cell is properly filled, it is capped, or sealed. A worker may wear herself out within a few weeks. Her ending is tragic, for she has been loyal, faithful, and untiring in her efforts.

THE FARMERS, MINERS, AND WARRIORS OF THE INSECT WORLD—THE ANTS

The inhabitants of the ant colony. No insects, except the honeybees, are more interesting to study than ants. Like the bees, the ants live in little colonies or nations which are excellent examples of community life. There are usually three well-distinguished kinds of individuals in a colony; namely, the *queens*, or fertile females; the *workers*, or sterile females, also called neuters; and the males.

The queens are much larger than the workers. At first they have wings and leave the nest for mating. Later they return

THREE MEMBERS OF AN ANT COLONY



Among the ants, as among the bees, there are males and females, and then there are workers, or neuters. This illustration shows a male, a female, and a worker.

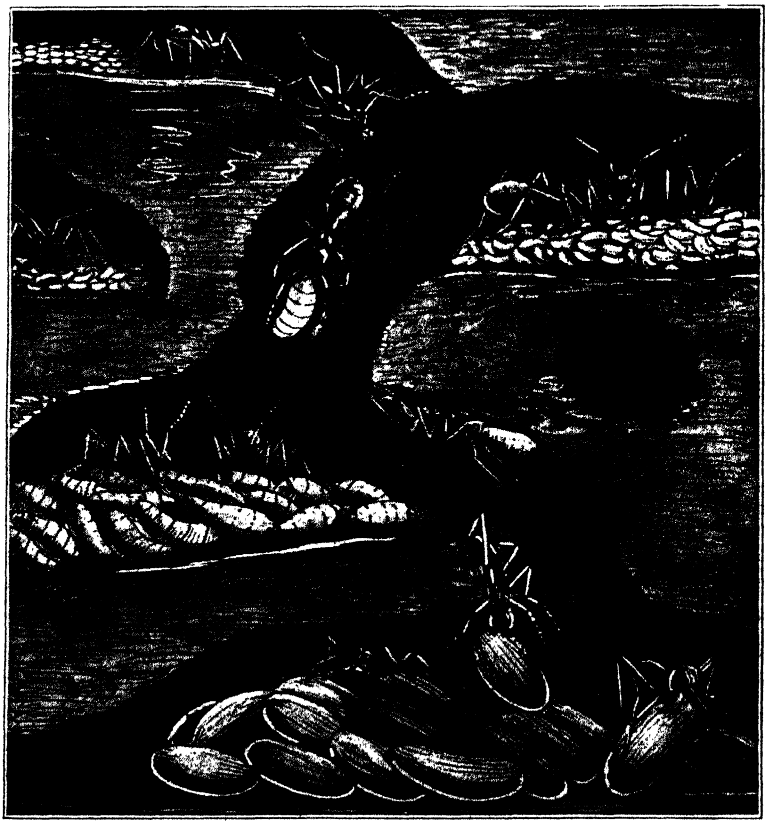
and tear off their wings, or the workers do it for them. Large colonies may have several queens, but a small colony usually has but one. Most of the ants in a colony are small wingless workers and are the ones we commonly see. These workers are females, but are not fully developed and normally do not lay eggs. Sometimes the workers include both small and large ants, the latter being known as "soldiers." The soldiers may be identified by their large heads and very powerful jaws.

The males are usually much smaller than the queens, but slightly larger than the workers. They are the winged members of the colony, are short-lived, and are seen about the nest only at mating time.

THE WONDERS OF AN ANT COLONY

A home underground. Most species of ants build their nests or homes underground, but occasionally they locate them under

THE UNDERGROUND HOME OF THE ANT



The illustration shows the classification of the larvae and pupae according to their stages of development. Many of the worker ants spend their time transporting the larvae and pupae to and fro, like nurses caring for the children in their charge.

a thin stone or even in an exposed place. Certain species tunnel corridors and rooms in old logs or stumps; others live in the stems of plants; a few make nests of paper or sew leaves together with silken threads.

The underground nest consists of many stories made up of irregular chambers and galleries. Although a part of the nest usually appears above the ground as a mound or anthill, most of it extends several feet underground. The mound is composed largely of such materials as bits of wood or parts of soil brought up from below the surface. The part beneath the ground provides protection from such enemies as mice, birds, and certain predaceous insects. Furthermore, sudden changes in temperature are not so noticeable in the deeper chambers. Supplies of food are safe from damage by rain except in cases of heavy storms. The chambers of the more complicated nests are used as granaries for food storage, as stables for the "ant cows" (aphids—plant lice), as nurseries for the larvae, and as sleeping quarters during winter. Thus ants are remarkable artisans, building complicated structures that provide for a high degree of specialization in the way they live and work.

AN ANT AND ITS COWS

Lynwood M. Chace

Here an ant herdsman is carefully watching over a small herd of aphids. The aphids produce a substance called honeydew, which the ants greatly relish and depend upon as food.

Life in the ant colony. There are several different ways in which new ant colonies are established. Usually after mating the queen descends to earth, removes her wings, and burrows a little chamber. Here she lays a number of eggs and waits weeks and even months for the larvae to mature. She cares for the hatching larvae herself, feeding them from her own body until they spin their cocoons, from which they emerge later as

neuters or worker ants. During all this time she has gone without food. Consequently the newly hatched workers are undernourished and undersized. Although this is the case, they soon take over the work of the colony, while the queen devotes all her time to laying eggs. They also feed and care for the later broods of workers.

After the queen has produced many broods of workers, she lays eggs that develop into males and females with wings. On a sultry day in summer, the males and females leave on a flight for mating. When the flight is over, the males either look for a convenient place to alight or fall exhausted to the ground. They can never return to the colony and consequently soon perish. The new queens shed their wings and enter the ground to make new nests and to form new colonies. In general, ants are long-lived, the workers living from four to seven years and the queens even longer.

Ants go to war! Certain species of North American ants frequently set out on warlike expeditions to capture the pupae in the nests of other ants. If they are successful, they either eat the pupae or carry them away. Later when the pupae develop they become "slaves" to the victorious ants. During a battle between two colonies every warrior seems able to recognize the members of its own army.

THE BEHAVIOR OF INTERESTING ANTLIKE INSECTS—TERMITES

Other interesting insects are the wood eaters known as termites. These little pests make their homes in decaying wood. They resemble ants in many ways, often being called white ants although they are not real members of the ant family. Like the true ants just described, however, they live in colonies. The members of the colony differ from those of the ant colony in that there is a royal pair, the king and queen, in addition to numerous workers and soldiers. There are also reserve males and females always on hand to take the place of either or both of the royal pair should death occur. In tropical countries termites are among the most abundant

A TERMITE SKYSCRAPER

J. J. Hirz

It is difficult to believe that such tiny creatures as termites can build a structure like this. Even this picture does not give an adequate conception of the size of a nest, because frequently about as much of the home is underground as appears above.

of all insects. Their home or "skyscraper" is an enormous domed mud structure sometimes reaching a height of twenty-five feet. There may be several million members in a single colony. Each termite is about half an inch in length.

INTELLIGENT BEHAVIOR IN ANIMALS

We have learned that tropisms, reflexes, and instinctive modes of behavior are inherited and are performed in much the same way by all members of a species. Intelligent behavior differs from instinctive behavior in that it must be learned independently by an animal after it is born. Thus we may define *intelligence* as the ability of an animal to learn by experience. A dog that refuses to chase an automobile because it has been whipped on previous occasions shows a kind of intelligence. The dog did not inherit the knowledge that it should not chase a passing automobile, but it evidently did inherit the ability to acquire such information and to remember it to advantage. Two phases of intelligence are memory and reasoning.

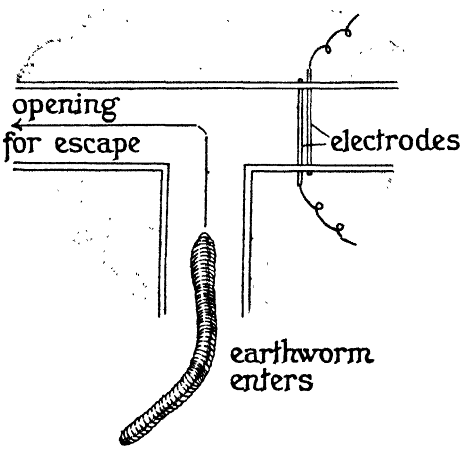
Recall of past experiences—memory. Past experiences leave an impression on the nervous system. We know this

from what we remember about past events. *Memory*, then, may be defined as a record of past experiences.

It is through memory that animals learn to return to certain places for food or to respond to particular calls. Dogs, for instance, have very good memories and learn many things. Birds soon learn to know and remember the people who feed them. Some birds will even eat from our hands. It is thought that migratory birds locate their routes, at least in part, by memories of landmarks along the way.

The earthworm that learned to remember. Even an earthworm will learn to avoid unpleasant experiences. An interesting experiment along this line was performed by Dr. Yerkes to find out whether such a simple nervous system as that of an earthworm is able to learn from experience. A piece of apparatus like that in the illustration at the left was constructed so that the earthworm had to turn one of two ways to escape.

HOW AN EARTHWORM LEARNED TO REMEMBER



After a hundred trials, including many unpleasant electrical shocks from the wire at the right, the earthworm remembered to turn to the left.

The right-hand passage was fitted up with an electric connection designed to give the earthworm a shock, whereas the passage to the left was free from obstruction. It required about one hundred trials before the earthworm learned to go always to the left. This experiment indicated that the earthworm is controlled almost entirely by a fixed behavior, but that it also has a nervous system that can be modified by experiences. In other words, it is capable of a slight degree of learning and remembering.

The difference between memory and reasoning. It has already been pointed out that both memory and reasoning are phases of intelligence. Reasoning, however, is a higher development of intelligence. When an animal chooses between several memories or puts certain ones together and makes a decision or decisions, the process is called *reasoning.* In such a case, the decision is always made before an action takes place. It becomes rather difficult at times, however, to decide whether certain acts are really examples of reasoning or merely examples of memory.

Reasoning in wild animals. Hornaday replies to the question of whether or not wild animals possess minds and a working intelligence (reasoning power) by answering, "Yes. Animals do reason. If any truth has come out of all critical or uncritical study of the animal mind that has been going on for two centuries, it is this. Animals do reason; they have always reasoned, and as long as animals live they will never cease to reason. The only real question is: How far does their intelligence carry them!"[1]

Dr. Hornaday thinks that animal intelligence cannot be properly measured when a wild animal is placed in an artificial contrivance, fitted with doors, cords, levers, passages, and what not, because the animal is frightened out of its normal state of mind. He believes that the only reliable way to measure wild-animal intelligence is to study the reactions of the animal in its natural surroundings.

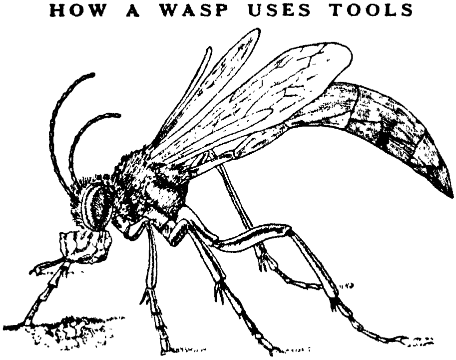
Did this bear reason? In the zoo at Edinburgh, Scotland, a polar bear was observed sitting on a rock projecting out into the water of a quarry. Visitors eager to feed the bear threw large pieces of bread toward it, but the pieces fell short of its reach. Instead of plunging into the water after them, the bear proceeded to scoop the water with its paw in order to set up a current. This current carried the pieces on to the bear. Surely such behavior on the part of this animal could only be considered an act of intelligence.

[1] **William T. Hornaday, *The Minds and Manners of Wild Animals.* Charles Scribner's Sons.**

More about reasoning in animals. The capacity for reasoning is far greater in man than in any other animal. Other than man, the dog and the horse are most often given credit for possessing the power of reasoning. This is probably because these animals are among man's closest associates.

Fur-bearing animals, which have been hunted and trapped for centuries, show remarkable ability to carry out thoughtful strategy. There is an authentic story of a wolverine that broke the thread of a set gun and then dragged the bait away without coming in range of the gun or setting it off. Surely mere instinct could not account for such a procedure. A coyote, attacking a range calf and finding that it cannot finish the job alone, hurries away and shortly returns with a companion to help it. There seems to be little question that such behavior is controlled by reasoning rather than by instinct.

HOW A WASP USES TOOLS



After the female Ammophila lays her eggs in a nest, she picks up a tiny pebble from the ground and hammers down the loose soil over the top.

Some authorities think that even certain insects show some signs of ability to reason. G. W. and Elizabeth Peckham, for instance, have discovered a tool-using habit among certain slender-waisted wasps. These tiny creatures dig holes in the ground in which to store caterpillars as food for their young. They next lay eggs in the caterpillars and cover up the holes. The eggs hatch and the pupae feed on the caterpillars. The interesting thing about the whole procedure is that the wasps use small pebbles as hammers to smooth the surface of their nests. This is probably done to prevent discovery by parasites or other insect enemies.

A living circle of defense. The musk oxen of the Arctic are famous for the strategy they employ in defending themselves

WILD CATTLE OF THE ARCTIC

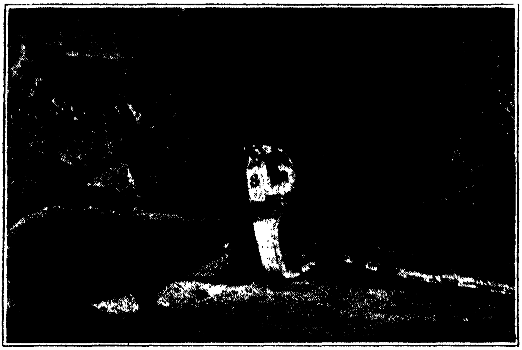
Courtesy Canada Department of the Interior

Arctic musk oxen are widely distributed in Arctic North America, but are decreasing in numbers. How do their habits differ from those of the cattle of more temperate climates to the south? What is there in the far North for them to eat?

and their young. These animals live in herds of twenty to thirty or more. Their large curved horns, which meet in massive bases across their foreheads, serve as effective weapons when they are attacked by the deadly Arctic wolves. When a wolf pack makes an attack, the musk oxen form a compact circle about their calves. With lowered heads, they make an impregnable defense of sharp horns as they stand facing outward. (See illustration.) Should one of the more daring wolves come near enough to make a breach in the circle, the nearest musk ox rushes from the line and drives him back. The charging bull, however, does not go farther than about twenty yards lest he be surrounded by the wolves in the pack. After the charge he immediately backs into his place in the living circle of defense. Wolves have come to recognize the strong defense of musk oxen and frequently pass by a herd without making an attack.

The courage and skill of the mongoose. The mongoose is a slender little animal about sixteen inches in length that seems to have a peculiar aversion to the poisonous cobra. At the

A MONGOOSE ABOUT TO ATTACK A DEADLY COBRA



Courtesy Eastman Kodak Company

The mongoose has been domesticated in certain countries, especially in the Orient, because of its usefulness in killing vermin. Its importation into the United States, however, has been forbidden because it multiplies rapidly and destroys many animals of value.

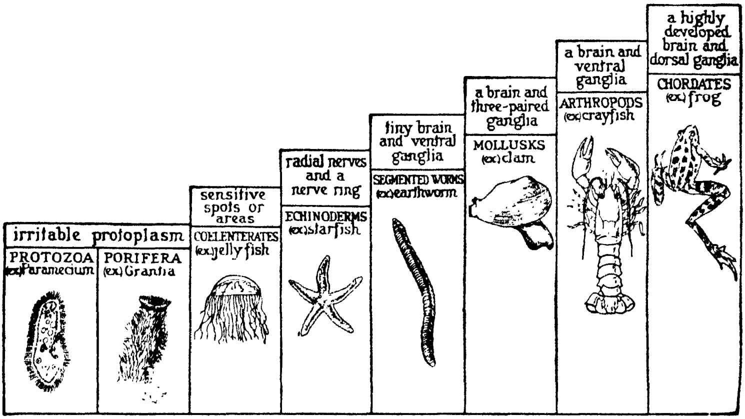
sight of this snake the mongoose fairly bristles with rage. It softly approaches the snake and makes a pretense of leaping at it. This causes the snake to strike again and again. The mongoose repeats its clever feinting, always being careful to evade the thrusts of the enemy. After many such parries the snake becomes dazed and uncertain in its movements. The mongoose is quick to take advantage of this condition and pounces upon the snake, seizing it by the back of the head and breaking its neck before it can offer resistance. This type of contest, in which one animal is able to wear down the strength of its opponent, is frequent in the animal kingdom.

Problem 3. What types of nervous mechanisms are found in various animals?

Before considering the complex nervous system of man, we shall study the simpler nervous systems of some of the lower animals. These animals include the Coelenterates, which have one of the simplest forms of nervous mechanisms, and such invertebrate animals as the starfish, clam, and crayfish.

One of the simplest nervous mechanisms. The simple nervous system of the Coelenterates may be illustrated by that of the *Aurelia* (ô-rēl′yȧ) (jellyfish). As shown in the drawing on the following page, this mechanism contains no such complicated structures as nerves, nerve centers, or brain. Instead, tiny *sensitive spots* form a ring within the tentacle-bearing rim of

THE NERVOUS MECHANISMS IN ANIMALS

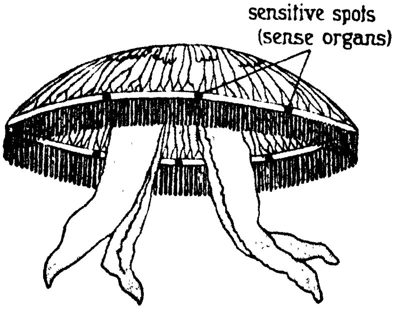


This drawing shows the increasing complexity of the nervous system from the lowest phylum of animals to the highest. (Some place the mollusks ahead of the arthropods.)

the animal. It is not entirely clear what kind of stimuli these spots are suited to receive. It has been demonstrated, however, that they are sensitive to gravity, to temperature changes, to light, and to chemical and mechanical action.

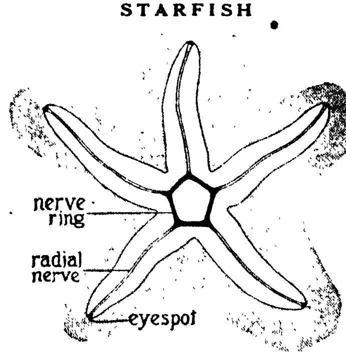
Radial nerves and a nerve ring. The *starfish* has a more highly developed nervous mechanism than the jellyfish, as may be seen from the illustration below. This nervous system is

NERVOUS SYSTEM OF A JELLYFISH



The Aurelia, a common jellyfish, has eight sensitive spots as shown here.

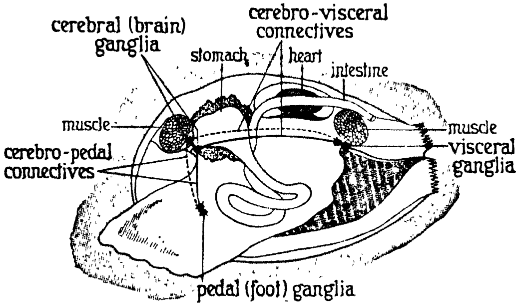
NERVOUS SYSTEM OF A STARFISH



How does the above nervous system compare with that of the jellyfish?

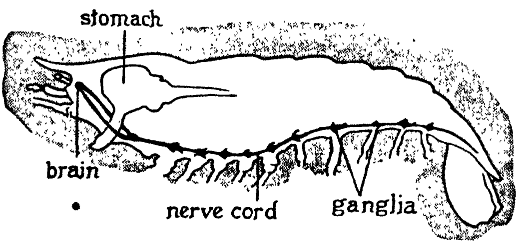
composed of *radial nerves* running from a *nerve ring* about the mouth of the starfish to the tip of each of its five arms or *rays*. At the tip of each radial nerve is a pigmented area that seems to be sensitive to light. This is called an *eyespot*. Branches of fibers and cells from the radial nerves and the nerve ring extend to all the radial organs. Thus in the starfish, as shown on the preceding page, we find the beginning of a centralization of nerves that is common to animals of higher groups or phyla.

THE NERVOUS SYSTEM OF A CLAM



The nervous system of the clam includes three pairs of ganglia. The working together of these ganglia indicates the beginning of a more highly developed nervous system.

THE NERVOUS SYSTEM OF A CRAYFISH



This illustration shows how the nerve connectives straddle the esophagus leading to the stomach and connect the brain to the ventral ganglia. Branches from the ventral ganglia and brain lead to various parts of the body.

The beginning of brainlike structures. Simple brainlike structures are found in the earthworm and in the various members of the *mollusk group*. The nervous system of such mollusks as the clam is made up of three pairs of *ganglia* (găŋ′glĭ-ȧ; singular, *ganglion*) or nerve centers. A study of the illustration near the top of this page will give some notion of the manner in which such a nervous system functions.

The central nervous system of the crayfish. The nervous system of the *arthropods* (är′thrō-pŏdz) is more highly developed than that of the mollusks. The drawing of the nervous

mechanism of the crayfish on the preceding page will show what this system is like. The crayfish has a *brain* in the back of its head from which two cords lead along its gullet and connect with a *ventral nerve* that extends the full length of its body. At various places in the body are groups of nerve cells called ganglia, from which nerve fibers pass out to the different sense organs and muscles. Thus the nervous system of the crayfish functions as a unit.

Problem 4. How does the nervous system in the human body function?

What man's nervous system does for him. We have learned that all living plants and animals respond to factors in their environment; that is, they are "alive" to their surroundings. The protoplasm in the cells of plants and in those of the lower animals is more or less responsive to stimuli. If we were to examine the phyla of the animal kingdom from the coelenterates through the vertebrates, we should find in all cases a nervous mechanism. In the higher animals this mechanism is a central nervous system that connects with special structures or sense organs. These special structures, such as eyes and ears, are more sensitive to stimuli than other parts of the body and are designed to receive certain kinds of stimuli. The nervous mechanism reaches its greatest complexity in the vertebrates, of which man is the highest type.

The important functions of the human nervous system may be summarized as follows:

1. It enables us to experience sensations and to keep in touch with the outside world through the stimuli that affect our sense organs.
2. It manages such "self-operating" activities as the beating of the heart, breathing, and glandular processes.
3. It enables us to control and coördinate our muscular activities.
4. It enables us to think, or display the highest type of behavior.

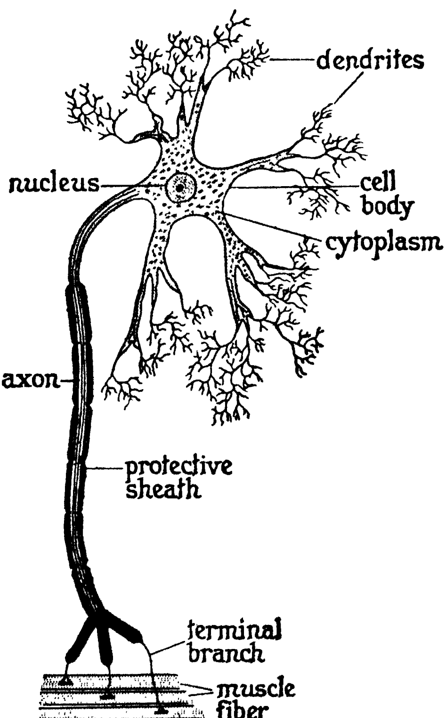
THE PARTS OF THE NERVOUS SYSTEM

Two great divisions. The nervous system of man consists of two intimately connected divisions: (1) *cerebrospinal* (sĕr′ē-brō-spī′năl), or central nervous system — *brain, spinal cord,* and *nerves;* (2) *autonomic* (ô′tō-nŏm′ĭk), or "self-running" nervous system, composed mostly of two chains of ganglia (nerve centers) along each side of the spinal column. Both systems are discussed on the following pages.

NEURONS AND BEHAVIOR

What neurons are. Nerve tissue is composed of irregular-shaped cells called *neurons* (nū′rŏnz). It is estimated that there are about sixty-three billion such cells in the human body. Each neuron consists of a cell body and two types of branches. The cell body is the enlarged portion containing the nucleus and cytoplasm. The branches that spread like those on a tree, or the *dendrites* (dĕn′drīts), form a sensitive area around the cell body. The long rodlike extensions from the cell body are called the *axons* (ăk′sŏnz). Some axons, such as those which extend from the spinal cord to the foot, are three feet or more in length. Each axon ends in branches much like the

A NEURON AND ITS PARTS



Using the drawing above as a guide, explain just how a neuron functions within the body.

dendrites. A number of axons bound together within a protective sheath form a *nerve.*

Neurons are combined in various ways to form nerve organs. The brain and spinal cord, for instance, consist of many neurons interwoven in a network of connective tissue. In some parts of the body, cell bodies and their radiating branches are held together in a swelling or knot known as a ganglion. A group of ganglia and their branches form a *plexus* (plĕk′sŭs).

Three types of neurons. The neurons that compose our nervous system are of three types—*sensory, motor,* and *associative neurons.* The sensory or *afferent* (ăf′ẽr-ĕnt) neurons receive impressions or impulses from end organs and transmit them to the spinal cord and the brain. The motor or *efferent* (ĕf′ẽr-ĕnt) neurons carry messages from the spinal cord to the muscles and glands. The associative or *connecting* neurons, located in the brain and spinal cord, connect sensory and motor centers.

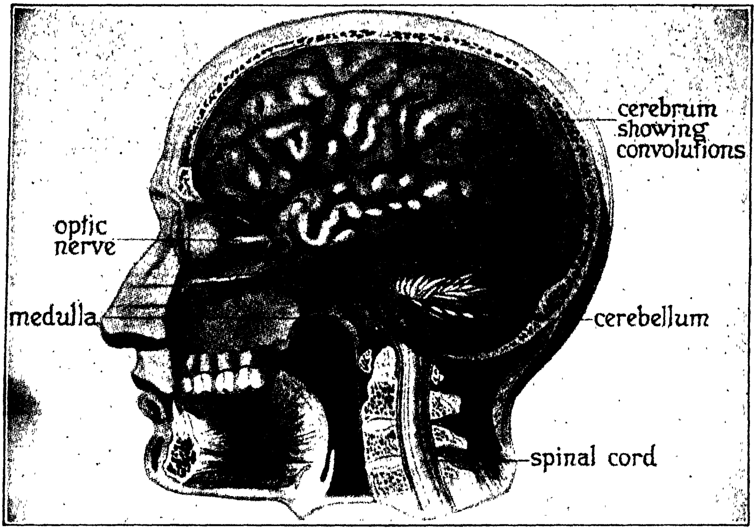
Where axon endings meet dendrites—the synapse. The nervous system is so arranged that the terminal branches of the axon of one neuron dovetail with the dendrites of another neuron, but do not actually meet them. Such a junction point is called a *synapse* (sĭ-năps′). When a stimulus affects the body, the sensation passes over a sensory neuron to a synapse, where it jumps the gap to a motor neuron that carries it on to the muscles as a message to act. Thus when we prick a finger the stimulus of pain is passed over a sensory neuron to a synapse, where it jumps to a motor neuron that leads back to the hand and causes us to jerk the finger away.

The Main Center—The Brain

The human *brain* may be likened to a vast switchboard in a modern telephone exchange, except that it is more complicated. When we use a telephone, messages pass back and forth on the same wire. In the nervous system, however, messages travel in only one direction. Certain neurons carry messages to the brain and others carry messages away.

Man's brain is much larger in proportion to his size than that of any other animal. In general, it weighs about one

HOW THE BRAIN APPEARS IN THE SKULL



Courtesy Spencer Lens Company

How has nature protected the delicate brain and spinal cord from injury?

forty-second as much as the entire body. In men, the average weight is about three pounds; in women, five ounces less. Formerly scientists thought that there was great localization of functions in the brain, but now they believe that there is much less.

The parts of our wonderful brain. The large upper portion of the brain is called the *cerebrum* (sĕr′ē-brŭm). It is divided into two *lobes* or *hemispheres*, which are connected by a mass of nerve fibers. The outer surface of the cerebrum, which is often called the *cortex* (kôr′tĕks), is composed of gray matter and contains many irregular folds or *convolutions* (kŏn′vō-lū′-shŭnz). The inner portion of the cerebrum is composed of white matter. Although it is not clearly understood just how the cerebrum works, it is known that it functions strongly in all conscious activity, such as voluntary acts, reasoning, and memory. Some psychologists think the cortex is the real center of mental activity. Thus we commonly refer to "gray matter" as the equivalent of intelligence.

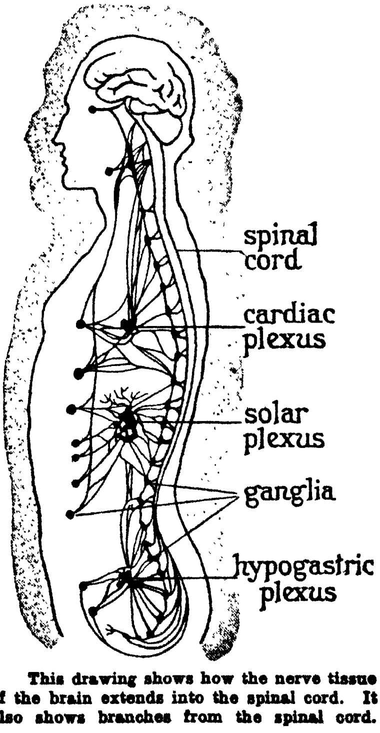
The *cerebellum* (sĕr′ē-bĕl′ŭm), or "hind brain," lies below the cerebrum. Little is known about its work, except that it seems to give us muscular coördination and a sense of balance.

The *medulla oblongata* (mē-dŭl′ȧ ŏb-lŏng-gā′tȧ) is the lowest or posterior part of the brain, or the enlarged beginning of the spinal cord. It contains the nerve centers that control respiration and circulation. Its branches also extend to the throat, and govern the acts of swallowing and speaking.

THE LARGE NERVE CABLE—THE SPINAL CORD

The *spinal cord,* which is a continuation of the nerve tissue of the brain, is a cylindrical cable incased in the hollow vertebral column. It is less than an inch across and is divided into right and left halves by two deep grooves. The white outer part is composed almost entirely of axons leading to and from the brain. The gray interior part contains the cell bodies of the neurons. (See the accompanying illustration.) Thirty-one pairs of nerves extend from the spinal cord to various parts of the body.

THE SPINAL CORD A CONTINUATION OF THE NERVE TISSUE OF THE BRAIN



This drawing shows how the nerve tissue of the brain extends into the spinal cord. It also shows branches from the spinal cord.

When voluntary muscular action takes place, messages originate in the brain and are transmitted to certain cells in the spinal cord. From here motor impulses are sent to the necessary muscles. The spinal cord also controls reflex actions, which, we have learned, are executed without orders from the brain.

The Self-running or Autonomic Nervous System

In addition to the central nervous system many ganglia and nerve trunks that make up the self-running or *autonomic nervous system* are distributed throughout the body. Along each side of the spinal cord is a double row of ganglia connected with the roots of the nerves that extend from the spinal cord. Certain other large ganglia belonging to the autonomic nervous system, together with their branches, form concentrated networks, called plexuses, in various parts of the body. Three of these important networks are the *cardiac* (kär′dĭ-ăk) plexus located in the chest cavity, the *solar* (solar) plexus in the "pit" of the stomach, and the *hypogastric* (hī′pô-găs′trĭk) plexus in the abdominal cavity.

The autonomic nervous system controls the involuntary muscles and glands of the body and makes possible the harmonious action of the internal organs.

THE OPERATION OF OUR NERVOUS SYSTEM

The sum total of all our responses constitutes our *behavior.* Part of this behavior is the result of inheritance and part of it is the result of learning. Thus a baby is born with part of its behavior already established. The *original nature* of the baby is made up of three primary factors, namely:

1. *Reflexes*—simple inherent responses, not produced by training
2. *Instinctive responses*—more complex inherent responses which can be slightly modified by training so as to become more useful
3. *Capacities* (aptitudes and abilities)—inherent mental equipment capable of being modified

Perhaps we can best understand the operation of the nervous mechanism by studying a few examples of behavior. We shall begin by observing some of the simplest forms.

The Reflex Act and Its Importance to Us

We have already noted that all animals show simple types of mechanical behavior called reflexes. (See page 533.) Since

these are only slightly subject to conscious control and some not at all, we are likely to underestimate their real importance. There are over fifty reflex patterns firmly established in man's nervous system. By considering the following list we shall appreciate how important some of them are:

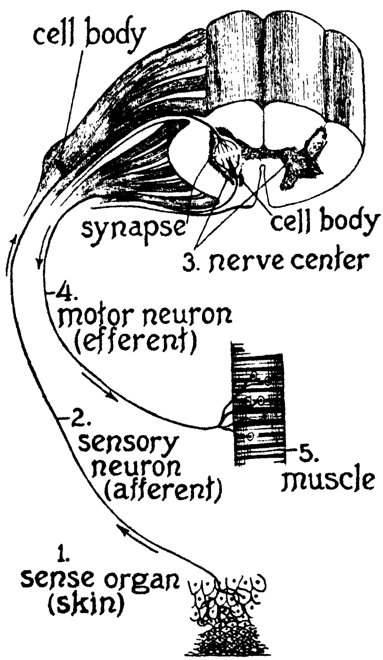
laughing	trembling	withdrawing hand (from pain)
scowling	snoring	changing size of pupil (to adjust the eye to light)
coughing	vomiting	
sneezing	gasping	winking (to protect and rest the eye)
crying	swallowing	jumping (at loud unexpected sounds)

The following explanation, with the illustration, shows how a simple reflex act takes place. Five parts are involved:

1. A *sense organ* to receive the impression
2. A *sensory* or *afferent neuron* to carry the impression to the nerve center
3. A *nerve center* to receive the impression and send a reply in the form of an order to act
4. A *motor* or *efferent neuron* to carry the order to a muscle or gland
5. A *muscle* or *gland* to act or carry out the order

Whenever we touch a finger to a hot object, we jerk it away instantly before we can think of what has happened. Such a reflex action is obviously useful. The accompanying illustration will help us to understand how this reflex action takes place.

THE PATHWAY OF A REFLEX



Using this drawing as a guide, begin with the skin and trace the mechanism involved in the completion of a simple reflex act.

Heat excites the nerve endings in the skin. The impression is carried along a sensory neuron to a synapse in the spinal cord, where it jumps a gap. The resulting impulse to act is carried over to a muscle that pulls the hand away from the flame. Very few reflex actions, however, are as simple as this. The nerves and nerve centers are so interlaced that several things may occur in response to a stimulus. For example, when we touch a finger to a flame, we may draw up a leg, jump back, or even cry out in pain. Such responses indicate that a nerve impulse coming from the skin may be transmitted to several different motor neurons. This explains why several reflex actions may take place from a single stimulus at the same time.

Instincts and Human Behavior

We have already noted earlier in this unit that instincts play a large part in the behavior of some animals. In the study of bees and ants we found little that might be attributed to reason or habit. If they are placed in a definite situation, there is only one way for them to respond, since a large number of reflex patterns are firmly established. This condition prevents such animals from learning very much.

Biologists and psychologists disagree as to the part instincts play in human behavior. Some authorities say that we have but few instincts and that these few are of little importance. All agree that reason, habit, and emotion are the strongest controls of human behavior. During infancy and childhood the instincts have little opportunity to function without interference. Continuous parental care and training cause the instincts to be greatly modified or supplemented by habits. As the normal child grows older and progresses through the various levels of school, he is capable of thinking more and more consistently.

Instincts common to human beings may be grouped under the following heads:

1. *Nutritive instincts*—unlearned activities concerned with the maintenance of life, such as food-getting and eating

2. *Defensive instincts*—such responses as hiding, flight, and the construction of shelter
3. *Reproductive instincts*—the activities of courting, mating, and parental care
4. *Social instincts*—responses to the presence or activities of other human beings

Habits and Their Importance to Us

Human beings are often referred to as "walking bundles of habits" because of the part that habits play in behavior. The reflexes and instinctive acts of early childhood are modified by training. These unlearned responses are not so definitely fixed as they are in the young of lower animals. The child experiments by the trial-and-error method until he finds better ways of doing things. Habits are important because they enable us to act without thinking directly about what we are doing, as in walking, dressing, eating, and many other activities. Education, therefore, must be greatly concerned with the formation of good habits.

WALKING MERELY A HABIT

The child learns to walk by experimenting with certain movements of the feet. Its first steps are very uncertain. The habit of walking is acquired by many repetitions.

Since there are billions of connections between the neurons in our bodies, habits are easily formed. In fact, we are constantly forming habits of one kind or another. Whenever a new act is performed, a new relation is formed between a sensory neuron and a motor neuron at the synapse between them. Every time an act is repeated, the relation at the synapse becomes closer, and consequently the nerve impulse passes more readily from the sensory neuron to the motor neuron that directs the act. Thus habits are fixed by repetition.

The laws of habit formation. Some years ago Dr. William James, a famous psychologist, declared that every person has within him an untapped capacity for work. He called attention to the fact that on certain occasions we are surprised at what we can do. This definitely shows that we do not live up to our full possibilities. As a result, Dr. James felt that we should give more attention to the formation of good habits. His laws of habit formation are:

1. Make a strong start.
2. Act on every opportunity.
3. Allow no exceptions until an act is learned.
4. Avoid fixed habits, always keeping an open mind and trying out new ways of doing things.

While it is somewhat difficult to break a bad habit, it is by no means impossible. The main thing is to set up a strong desire to get rid of the habit. The substitution of a good habit for the bad one will probably get the best results.

INTELLIGENCE

What intelligence is. *Intelligence* has been defined briefly as the ability to learn. Although it seems to be strongly related to the gray matter of the cortex of the brain, many psychologists think it results from the functioning of the whole nervous mechanism. This does not mean, however, that because a child is born with a nervous mechanism capable of doing mental work of a certain quality, he is sure to do such work. Other factors, as health, incentives, and ambition, have a part in the final achievement.

The expression used so often by educators, "We learn by doing," is true, for learning takes place only during activity. A teacher cannot pour education into the pupil as though he were filling a pitcher at a well. Learning is a very active process of reacting by the learner.

How intelligence is measured. Several tests have been designed to measure intelligence. Most of these tests are based upon the abilities a person should possess at various ages from

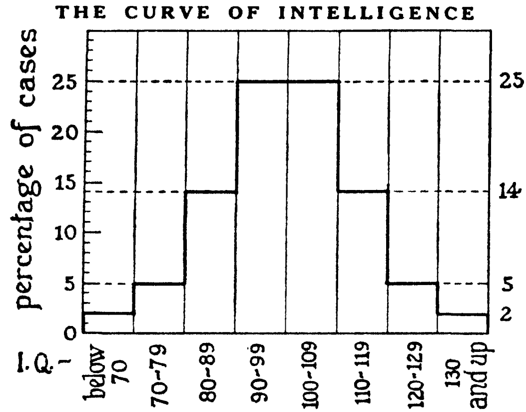
early childhood up to sixteen or eighteen years of age. The experts who have prepared these tests have established *norms* for each age. This means that they know, for example, what score an average child of ten should make. If at that age he makes the average score expected of a ten-year-old child, his "I. Q." is said to be $\frac{10}{10}=1.00$ or 100 (the decimal point is omitted). If, however, the ten-year-old makes a score equal to that expected of a twelve-year-old child, his I. Q. is 120. We can see from these illustrations that an intelligence test aims to establish a definite ratio between the *mental age* (M. A.) and the *chronological age* (C. A.), the actual age in years. This ratio is called the *intelligence quotient,* or I. Q. Some psychologists prefer to call this ratio the probable learning rate, or P. L. R., because it is supposed to indicate how rapidly a person should be able to learn at a given age.

Let us now retrace the steps in arriving at the I. Q. or the P. L. R.

1. Since the child is ten years of age, his chronological age is expressed as C. A. = 10.
2. Since he makes a score equal to that of an average twelve-year-old child, his mental age is expressed as M. A. = 12.
3. His I. Q. or P. L. R. is found by dividing his M. A. by his C. A. $\frac{\text{M. A.}}{\text{C. A.}}=\text{I. Q.}$ Substituting and dividing, we get $\frac{12}{10}=1.20$ or 120.

According to this formula, if the ten-year-old child had a mental age of eight, the I. Q. or P. L. R. would be $\frac{8}{10}=.80$ or 80.

An I. Q. or P. L. R. of 90 to 110 is usually considered normal. Only about 3½ per cent have an I. Q. or P. L. R. of 125 or more, and only 1 per cent of 140 or more. Those having 140 or more are usually considered geniuses. Although the I. Q. or P. L. R. serves as an index to what a person may be expected to learn, it is by no means the only index, as interest and persistent effort are also important factors.



This chart shows the approximate distribution of intelligence as it has been found by testing large numbers of children. From the heavy line tell the highest, lowest, and average I. Q. The height of each column represents the percentage of children at each ability level.

It is impossible, of course, to measure intelligence accurately. To begin with, intelligence is so complex that no fully adequate mental test can be made. Then, too, the physical condition of the person at the time he takes a test may affect the results. It is also necessary that a test be properly given and that the person tested be in the right frame of mind. In view of all these things two or three tests should be given before a safe conclusion can be reached as to a person's intelligence.

How We Come into Touch with the World about Us—The Five Senses

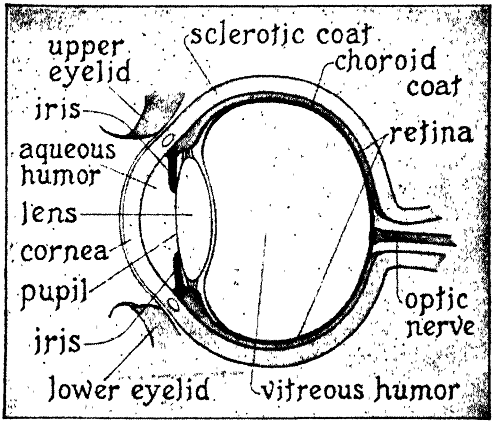
Some of the afferent nerves that carry impulses or messages to the central nervous system have their beginnings in the end organs of the special senses. The most important of these end organs are the eye and ear, through which we see and hear. In addition there are end organs of feeling, taste, and smell. Those associated with feeling (touch, heat, cold, and pain) are located in the skin; those associated with smell, in the membrane of the nasal passages; and those of taste, in the mouth, principally upon the tongue. It is largely through these end organs that we learn what is going on about us.

The cameras of the body, the eyes. A large part of our education and a great deal of the pleasure of living comes through the proper functioning of the eyes. Nature has been extremely

careful to protect the eyes from injury by setting them in bony sockets. Automatic shutters, the eyelids, assisted by eyelashes and eyebrows, keep foreign substances from reaching the tender membranes of the eyeballs. Tear glands furnish moisture and wash away particles of dust.

How we see. The structure of the eye is shown in the accompanying drawing. When rays of light fall on an object, they are reflected and enter the eye through an opening called the *pupil.* When these rays reach the *lens,* they are bent in their course so that after they pass through the fluid part of the eye, the *vitreous* (vĭt′-rē̇-ŭs) *humor,* they are brought to a focus upon the *retina* (rĕt′ĭ-nȧ), the sensitive coat in the rear. The nerve endings which spread out over the surface of the retina are stimulated, and the impulses are carried over the *optic nerve* to the cerebrum, resulting in sight.

PARTS OF THE HUMAN CAMERA



Explain how the functioning of the human eye compares with the operation of an ordinary camera.

Our sound-wave receivers—the ears. We look upon the receiving set of a radio as a marvel in modern invention. Perhaps we have never paused to think, however, that we have receiving sets in our own bodies. These are our ears.

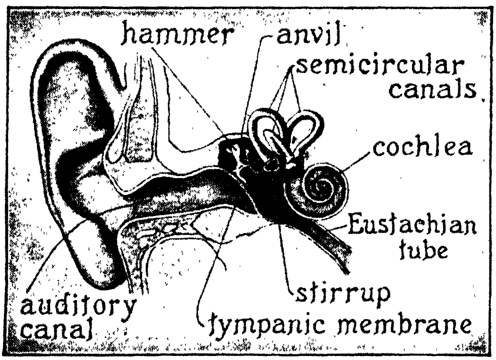
Sound comes to us in vibrating waves. Some of these vibrations arrive as infrequently as eight or ten vibrations a second. Others come as frequently as forty or fifty thousand a second. The pitch of sound is determined by the frequency with which the vibrations reach the ear.

How we hear. The ear is divided into three distinct parts: the *outer ear,* the *middle ear,* and the *inner ear.* Of all these

parts, the outer ear is the least important. It merely consists of a combination of cartilage and skin so shaped as to collect the waves of sound. The opening into the outer ear is called the *auditory* (ô′dĭ-tō-rĭ) *canal.* It is closed at the inner end by a tightly stretched membrane, the *tympanic* (tĭm-păn′ĭk) *membrane,* or *eardrum,* which separates the outer ear from the middle ear. Sound waves pass along the auditory canal and strike against the eardrum, causing it to vibrate.

The middle ear is bridged with a chain of three little bones called the *hammer, anvil,* and *stirrup.* The hammer rests directly against the eardrum. The vibrations of the eardrum are transmitted to the hammer, next to the anvil, and then to the stirrup, and thus reach the inner ear.

THE PARTS OF OUR HEARING MECHANISM



Explain from this drawing exactly how we hear.

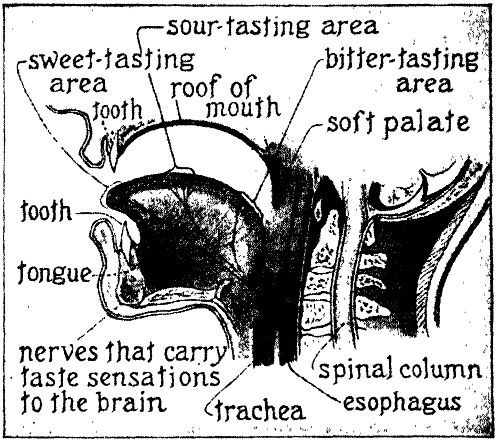
The part of the inner ear that receives the vibrations is known as the *cochlea* (kŏk′lē-ȧ). This is a spiral-shaped tube filled with a fluid and lined with sensory cells. The vibrations of the stirrup cause a rhythmic movement of the fluid that corresponds to the vibrations that enter the ear. The sensory cells take up the vibrations in the liquid and transmit them over the *auditory nerve* to the cerebrum. It is in this way that we hear.

The skin an important sense organ. We often think of the skin as the seat of feeling, but it is really the seat of four different senses, (1) *touch,* (2) *cold,* (3) *warmth* or *heat,* and (4) *pain.* Special nerve endings in the *dermis* or underlayer of the skin receive each of these sensations. Like the sensations of sight and sound, the sensations from these special nerve

endings are transmitted to the cerebrum. The illustrations on pages 273 and 559 show what the nerve endings are like.

The "partner" sense — taste. The sense of taste is sometimes called the "partner" sense, for it is closely allied with the sense of smell. It depends upon end organs called *taste buds,* located chiefly on the tongue. Each taste bud is composed of from ten to sixteen taste cells that pass the sensation to nerves to be carried to the brain. A substance must be dissolved before it can be tasted. This explains why some foods have very little taste and some none at all. When we eat an onion, for instance, we really smell it rather than taste it. This accounts for the fact that some foods have no taste when the nose is "stopped up" from a cold.

THE PARTS OF OUR TASTING MECHANISM

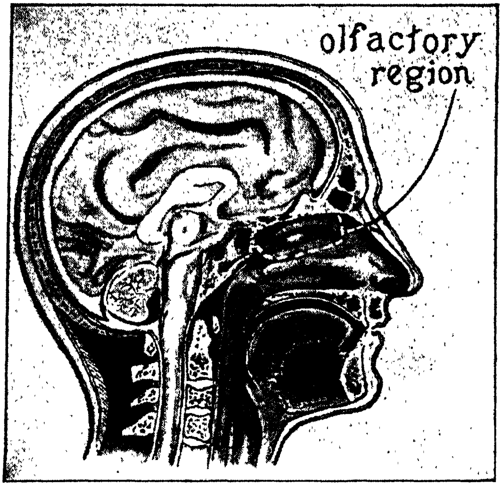


Explain from this drawing how we experience the sensation of taste, in its various forms.

It is interesting to note that the tongue is mapped out into different taste areas. A *sweet-tasting* area is located at the tip of the tongue; a *bitter-tasting* area in the back; and a *sour-tasting* area along the sides. *Salt-tasting* buds seem to be equally distributed over the entire surface of the tongue.

The sense of smell. Although our sense of smell is not so highly developed as that of certain other members of the animal kingdom, it is far keener than we sometimes realize. It has been calculated that some substances can be detected if they weigh only one thirty-billionth as much as the air they are in. Another fact that should impress us is that it takes more than twenty thousand times as much of a substance to

WHERE THE SENSE OF SMELL ORIGINATES



This illustration shows the sensitive *olfactory* region.

stimulate the taste organs as it does to stimulate the organs of smell.

We receive the stimuli of an odor through great numbers of long, slender, rod-shaped cells in the membrane that lines the upper part of the nose. The accompanying illustration shows where these cells are situated. When we breathe air into the nasal passages, minute particles of a substance pass over the cells in the sensitive region, stimulus is transmitted by the *olfactory* (ŏl-făk′tô-rĭ) *nerve* to the brain, and we experience an odor.

SUGGESTED ACTIVITIES

I. Self-Organization Summary

A. Plant Behavior
1. Explain five tropisms exhibited in plants.
2. Compare the responses of plants and animals.

B. Animal Behavior
1. Cite examples of animal behavior that illustrate tropisms, reflexes, instinct, memory, and reasoning.
2. Describe the organized social and colony life of bees and ants.
3. Relate at least two incidents of interesting animal behavior described in this unit.

C. Nervous Mechanisms in Animals
1. Trace the progressive development of the nervous mechanism in animals, beginning with the jellyfish and continuing to the vertebrates.

D. The Human Nervous Mechanism
   1. State four ways in which man is served by his nervous system.
   2. How does each of the leading parts of the nervous system function?
   3. What three primary factors make up the original nature of man? Give examples of each.
   4. What is meant by intelligence? How is it measured?
   5. Explain briefly how each of the five sense organs functions.

II. Laboratory Study

A. Follow the instructions given in Problem 1 and conduct experiments to illustrate tropisms in plants.
B. Prepare a slide containing a droplet in which living Paramecia occur. Heat a needle and place it in one side of the droplet. How do the Paramecia respond?
C. Study the various sensory structures of butterflies, grasshoppers, and crayfish.
D. If materials are available and time permits, arrange an observation hive for the purpose of making an extended study of the social and colony life of bees.
E. Dissect certain animals, such as a frog, for the purpose of tracing the nervous system.
F. Make microscopic studies of prepared slides of nerve tissue.
G. Use models of the eye and ear to locate and study the various parts.

III. Display Posters

A. Enlarged sketches of the sensory structures of animals.
B. Charts listing instinctive acts, reflexes, and acts of intelligence observed in lower animals. Pictures illustrating some of these forms of behavior may be found in magazines and newspapers.
C. Charts, curves, and graphs emphasizing data concerning intelligence.

IV. Special Reports

A. Sensitive plants
B. The use of tools by animals
C. Home-building among animals
D. Craftiness in animals

E. Warfare among insects
F. The value of psychology
G. Intelligence testing

REFERENCES[1]

1. Barrows, William Morton. *Science of Animal Life.*
   a. Nerve-muscle activity, pp. 45–56
   b. The use of the nerve-muscle system, pp. 57–69
   c. Complexity and coördination in animals, pp. 133–141
2. Hornaday, William T. *The Minds and Manners of Wild Animals.*
   a. The brightest minds among American animals, pp. 54–61
   b. The true mental status of the gorilla, pp. 93–100
   c. The morals of wild animals, pp. 219–224
   d. Wild animal criminals and crime, pp. 286–301
3. Maeterlinck, Maurice. *The Life of the Bee.*
4. Needham, James G. *The Animal World.*
   a. How animals get about, pp. 78–83
   b. How animals defend themselves, pp. 83–90
   c. The ways of animals, pp. 94–103
5. Shipley, Sir Arthur E. *Life.*
   a. Movements in plants and animals, pp. 115–132
   b. Rhythm in protoplasm, pp. 133–159
6. Transeau, Edgar Nelson. *Science of Plant Life.*
   a. Leaves in relation to light, p. 37
   b. Response of roots to gravity, light, and water, pp. 182–183
7. Thomson, Sir J. Arthur. *Riddles of Science.*
   a. Are animals ever afraid? pp. 71–76
   b. Why do we fall asleep? pp. 55–59
   c. Why must we die? pp. 146–155
   d. Do plants behave? pp. 215–230
   e. Do animals ever use tools? pp. 267–271
8. Washburn, Margaret. *The Animal Mind.*
   a. The mind of the simplest animals, pp. 33–46
   b. Higher mental processes, pp. 328–381
   c. The affective factors in the animal mind, pp. 382–403
9. Wheeler, William M. *Social Life among the Insects.*
   a. Insect societies, pp. 3–43
   b. Social insects—bees and wasps, pp. 43–91

[1]The pages listed here are those found in the editions indicated in the alphabetical list of references given at the end of this book.

10. *Book of Popular Science, The.*
    a. Animals that behave like men, Vol. 1, pp. 207–222
    b. Man's complex nerves, Vol. 6, pp. 1961–1969
11. *Compton's Pictured Encyclopedia.*
    a. Intelligence tests, Vol. 7, pp. 96–97
    b. Our acrobatic friends of forest and jungle, Vol. 9, pp. 225–230
12. *New Wonder World, The.*
    a. The five senses and others, Vol. 10, pp. 181–229
    b. Have plants any consciousness? Vol. 10, pp. 300–303
13. *World Book Encyclopedia, The.*
    a. Social life of the wasps, pp. 7658–7661
    b. The brain and its parts, pp. 918–921

VISUAL AIDS

FILMS (16 mm.)

A. Harvard Film Service, Cambridge, Massachusetts.
   1. Reactions in Plants and Animals. 1 reel, sound, $50.00. Presents a detailed study of tropistic movements of plants and of various reactions of animals
B. Y. M. C. A. Motion Picture Bureau, New York City.
   1. Ants. 1 reel, silent, $1.50 per day.
   2. Eyesight. 1 reel, silent, $1.50 per day.
   3. Bees and Spiders. 1 reel, silent, $1.50 per day.
C. Bray Pictures Corporation, 729 Seventh Avenue, New York City.
   1. How You See. 1 reel, silent, $8.80.
      Uses animated diagrams and photography
   2. How We Hear. 1 reel, silent, $8.82.
      Explains the structure and function of the human ear
D. U. S. Dept. of Agriculture, Washington, D. C.
   1. Realm of the Honeybee. 4 reels, silent, free.

CHARTS

Series	*Titles*
A. Pfurtscheller Zoölogy	Starfish No. 11
	Clam No. 2
	Perch No. 22
	Frog No. 27
B. Frohse Anatomical	Nervous System of Man No. FA3

UNIT ELEVEN

REPLENISHING THE WORLD WITH LIFE

SUGGESTIONS TO THE TEACHER

This unit aims to present the story of how life passes from one generation to another and is thus perpetuated on the earth. Certain forms of reproduction have already been presented in other units. Some discussion of mitosis, for instance, was given in Unit Two. The reproduction of Marchantia, ferns, pines, and most of the phyla of animals was treated in Unit Seven. This unit presents other examples of reproduction and so summarizes the topic as to give a more nearly complete picture of it.

The unit is somewhat technical in places, but the many concrete illustrations will help to carry the story. In the study of reproduction among plants much demonstration work may be done, presenting, for example, such methods as layering, bud grafting, and growing from underground stems. In the study of reproduction among animals the chief concern should be to show that the processes become more complicated in higher forms of life.

OBJECTIVES

I. Facts and principles

A. To observe that all life forms are equipped for prodigal reproduction of their kind
B. To study reproductive processes of various types
C. To note the similarities and differences in the reproductive processes of plants and animals

II. Attitudes

A. To develop a scientific respect for reproduction and a consequent wholesome attitude toward it
B. To appreciate how definitely nature has provided for the reproduction of all life forms, from the lowest to the highest
C. To appreciate the odd reproductive adaptations of certain forms of life, such as that of the cuttlefish as explained in this unit
D. To note that plants and animals may be classified in a general sequence from simple to complex on the basis of their reproductive processes
E. To comprehend and use intelligently the scientific vocabulary involved

UNIT ELEVEN

REPLENISHING THE WORLD WITH LIFE

A HANDSOME LITTER OF FOX HOUNDS

Lynwood M. Chace

The chief concern of all living things is to replenish the world with their kind.

ONE OF THE MYSTERIES OF LIFE

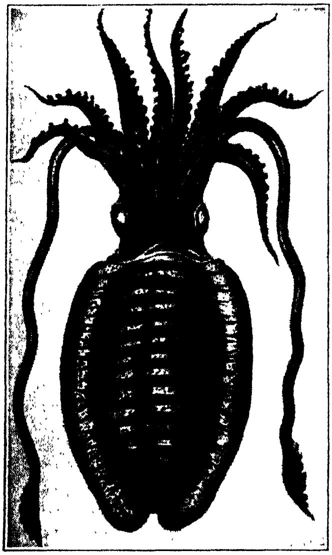
PREVIEW

Of all the mysteries of nature perhaps none is greater than that of reproduction. To every living organism has been given the power to bring other similar organisms into existence so as to replenish the world with its kind. In higher forms of life reproduction is usually brought about by a sexual process involving the union in some manner of an egg with a sperm. From this union a new "magic cell" which gives rise to a new organism is produced. In lower forms of life, reproduction is accomplished in many varied ways. It will be interesting to see how one of these forms reproduces its kind. Let us consider an inhabitant of the sea known as the cuttlefish.

The cuttlefish is truly one of nature's oddities. Its brown body, spotted with purple, is less than a foot long. Because

it has arms and sucker-like tentacles attached to its head, it is sometimes called a head-footed animal. It uses these arms and tentacles for moving, capturing food, and defending itself. The male, however, makes another use of them. This is for the purpose of reproduction. By means of an arm he deposits sperms in the mantle cavity of the female. Here the eggs undergo fertilization, flow out from this cavity, and become attached to plants in the water. Thus it is that the newly born begin their lives.

AN ANIMAL WITH A STRANGE METHOD OF REPRODUCTION



The cuttlefish is found in nearly all parts of the world. It is very small, usually about nine inches in length. How does it accomplish reproduction?

Cuttlefish are unique in the peculiar adaptation of the reproductive process by which they bring eggs and sperms together. In the various groups of the animal kingdom a somewhat uniform method prevails. The following problems cover the general principles involved in reproduction among both plants and animals.

PROBLEMS

1. **How do plants replenish the world with their kind?**
2. **How do animals replenish the world with their kind?**
3. **How do plants and animals care for their offspring?**

Problem 1. How do plants replenish the world with their kind?

The reproductive processes of all plants and animals, though they differ in some respects, reduce to two general methods, the sexual and the asexual, described on the following pages.

·The cuttlefish reproduces by the sexual method. This means that two different kinds of sex cells, male and female, are united. The two uniting cells are called *gametes* (găm′ēts), the male cell being known as a *male gamete*, or *sperm;* the female cell, as a *female gamete*, or *egg.*[1] The actual union of the contents of two such gametes, as we already know, is called *fertilization.* The new cell formed by the union of two gametes is called a *zygote* (zī′gōt), and the organism that develops from it is, in its early stages, called an *embryo* (ĕm′brĭ-ō).

In the asexual method of reproduction a part of the body of an organism is dissociated from the parent body and becomes a new organism. There are three forms of asexual reproduction:

1. *Cell division* or *fission*
2. Formation of *spores*
3. *Vegetative processes,* such as:
   a. Budding
   b. Extending runners
   c. Layering
   d. Growing from underground stems
   e. Grafting
   f. Regeneration

Cell division occurs among the one-celled plants and animals. This refers to the division of a cell into two new cells, each of which takes on the characteristics of the old. Spore reproduction occurs when special reproductive cells break away from the body of the parent and produce new organisms. A further explanation of this method will be given later in the unit. Vegetative reproduction generally refers to the separation of a large part of an organism from the parent body and the development of this part into a new organism. For example, if portions of the stems (cuttings) are taken from a rose bush and planted, they will grow into new plants. Vegetative forms of reproduction, such as budding, layering, and grafting, will be treated more fully later in the unit on pages 577–581.

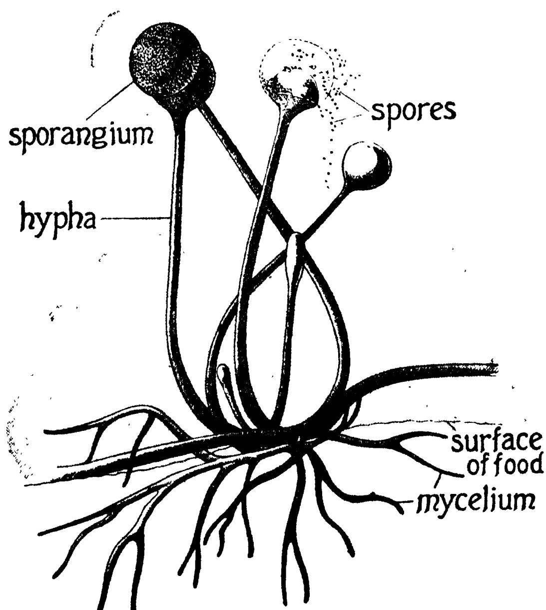
[1] In a discussion of plant reproduction the term *antherozoid* (ăn′thĕr-ō-zō′ĭd) or *spermatozoid* (spûr′mȧ-tō-zō′ĭd) is frequently used instead of *male gamete* or *sperm;* and the term *oösphere* (ō′ō-sfēr) instead of *female gamete* or *egg.*

ASEXUAL REPRODUCTION OF PLANTS

Production of New Plants by Cell Division

It is largely among the simple plants, such as algae and fungi, that we find reproduction by *direct cell division.* Bacteria, for instance, which are one-celled fungus plants, reproduce by a process known as *fission* (fĭsh′ŭn). In this process one cell merely divides into two. Fungi and certain algae reproduce by a more complex form of cell division known as *mitosis,* or indirect cell division, in which there is a division of chromosomes, as explained on pages 78–79.

AN EXAMPLE OF REPRODUCTION BY SPORES



The mold reproduces asexually. The bursting of the ripened spore case (sporangium) frees the spores, each of which may grow into a new mold plant.

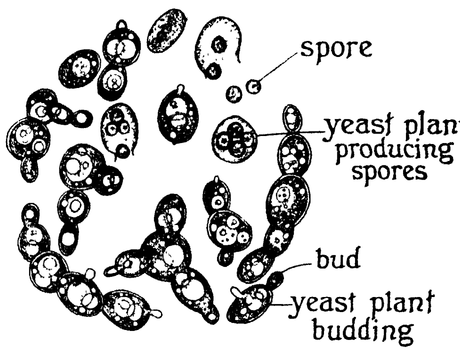
New Plants by Means of Spores

How the black mold reproduces by means of spores. Good examples of reproduction by *spores* in plants may be found

among the fungi. The black mold so often found on stale bread, for example, commonly develops *sporangia* (spŏ-răn′-jĭ-*ȧ*; singular, *sporangium*), or *spore cases*, at the tips of the *hyphae*. The protoplasm within the sporangia breaks up into special cells or spores. When these spores are ripe, the sporangia burst open and the spores are scattered about.

Other examples of spore reproduction. Spores usually have thick walls about them which enable them to overcome unfavorable conditions. Yeast cells, for example, break up into spores when conditions become unfavorable, because the spores can withstand dryness and high temperature much better than the regular cells can.

ANOTHER EXAMPLE OF REPRODUCTION BY SPORES



This diagram of yeast plants shows the breaking up of certain cells into spores. Each spore, of course, may develop into a new plant.

Certain bacteria, in order to withstand unfavorable conditions, also develop spores with thick walls. Such bacteria are called *spore formers*. The bacterium which causes lockjaw, *Bacillus tetanus*, is an example. When surgical instruments are being sterilized, it is necessary to expose them to dry heat for one hour at a temperature of 320° Fahrenheit, or to steam them under pressure for twenty minutes at a temperature of 248° Fahrenheit, to make sure that all the spores of dangerous bacteria are killed. Extreme care is necessary at all times.

Other organisms that reproduce by spores are mushrooms, shelf fungi, rusts, and smuts.

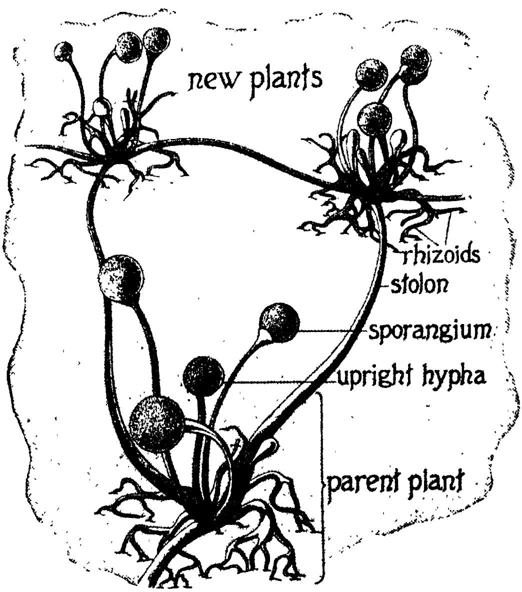
New Plants by Vegetative Reproduction

Spirogyra may reproduce vegetatively. Although Spirogyra reproduces most commonly by cell division, it may also reproduce by a vegetative process. A strand or a thread containing

a number of cells may break into two or more parts. Each part may then continue to grow as a separate individual by further cell division in the same manner.

New plants by budding. *Budding* is merely a slight variation of cell division. Yeast reproduces more commonly by this method than by producing spores. In budding, a projection consisting of cytoplasm (protoplasm other than that in the nucleus) and certain nuclear material pushes out from the cell wall. Finally, the projection separates from the parent cell and grows into a new plant. This method of reproduction, of course, has no relation to the budding of woody stems.

REPRODUCTION BY RUNNERS



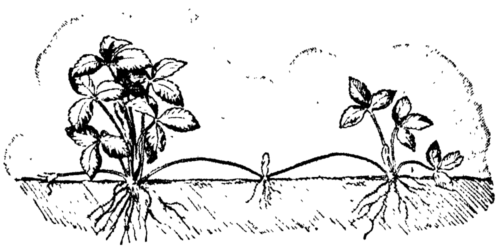
This drawing shows how bread mold or black mold sends up runner-like branches from the surface known as stolons. The new plants then grow upon these stolons.

New plants by runners and layering. Although bread mold, sometimes called black mold, reproduces asexually by spores, it also carries on vegetative reproduction by *runners*. When it begins to grow on a piece of bread, it sends up runner-like

branches from the surface called *stolons* (stō′lŏnz). New hyphae or new plants then grow upon the stolons.

Some of the higher types of plants, besides reproducing by seeds, frequently reproduce asexually by runners. Strawberries, for example, send out runners along the surface of the ground from which new plants develop. Grasses, such as the creeping bent which is used on golf greens, reproduce vegetatively by runners.

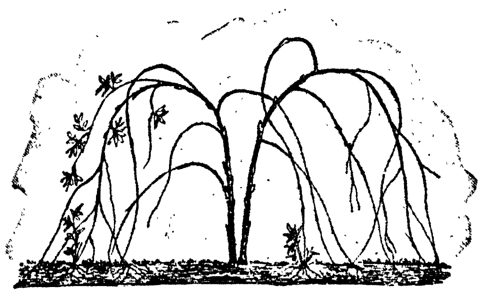
REPRODUCTION BY RUNNERS



When the slender runners of the strawberry take root in the ground, they develop into entirely new plants.

A process called *layering* is practiced with certain trees and shrubs as an added means of multiplying plants. When an aërial branch is bent down to touch the soil, it sends roots into the ground and a new plant develops. Gooseberries, blackberries, grapevines, and many ornamental shrubs, such as Forsythia, may be propagated or reproduced in this manner.

REPRODUCTION BY TIP LAYERING



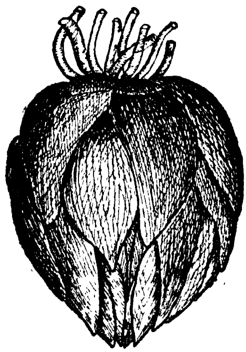
When branches of the black raspberry come into contact with the ground, they take root and form new plants.

New plants by underground stems. Some plants have *underground stems* from which aërial branches arise, forming new plants. The potato, for instance, is the enlarged part of an underground stem called a *tuber*. The enlargement comes from the presence of stored food. The potato has on its surface a number of *eyes* or *buds*. Under favorable conditions each bud sends up a shoot which is the beginning of a new plant.

Another common form of underground stem is the *rhizome* or *rootstalk*. Plants that may reproduce from rhizomes are the fern, iris, Canada thistle, and water lily.

Certain other plants, such as the tulip, lily, hyacinth, and onion, grow from *bulbs*. A bulb is really a cluster of thick scalelike bases of leaves that have grown from the tip of a small underground stem. These leaf bases are thick because they have food stored in them. If we should cut open a bulb, little buds would be found between the leaves. It is from these buds that new plants arise when bulbs are planted.

A BULB



Courtesy United States Department of Agriculture

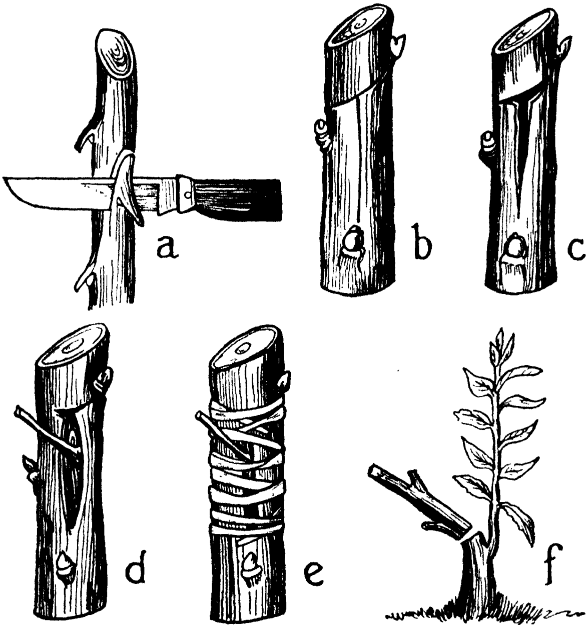
A bulb is a cluster of thick scalelike bases of leaves.

New plants by growth upon other plants. By a process called *grafting*, the stem of one plant may be made to grow upon that of another. Thus the stem of a tree that produces excellent fruit may be grafted upon the stem of a tree that produces inferior fruit. The grafted stem then grows and produces its own characteristic fruit. Grafting is widely used because it provides a surer and more rapid means of getting desired fruits than does growing them from seed. Only plants of the same species or of closely related species, however, can be grafted successfully.

The grafting process consists of cutting a stem or bud from a plant and of bringing its cambium or growing layer into contact with the cambium layer of another plant so that the two may unite. The joint is then tied with a string for support and is coated with grafting wax for protection. The stem upon which another is grafted is called the *stock*. The stem that is grafted is called the *scion* (sī′ŭn).

Regeneration in plants. Sometimes when a part of a plant has been removed, the part is replaced by a process known as regeneration. For example, when the growing tip of a lilac stem has been removed, new branches arise from undeveloped buds and the growth of the stem continues.

REPRODUCTION BY GRAFTING



These drawings illustrate the following steps in grafting:
a. The bud is cut from the parent plant.
b. An incision is made in the stem of another plant.
c. The incision is opened to make room for the bud.
d. The bud is inserted.
e. The bud and stem are securely wrapped.
f. The bud grows into a new plant on the old stem.

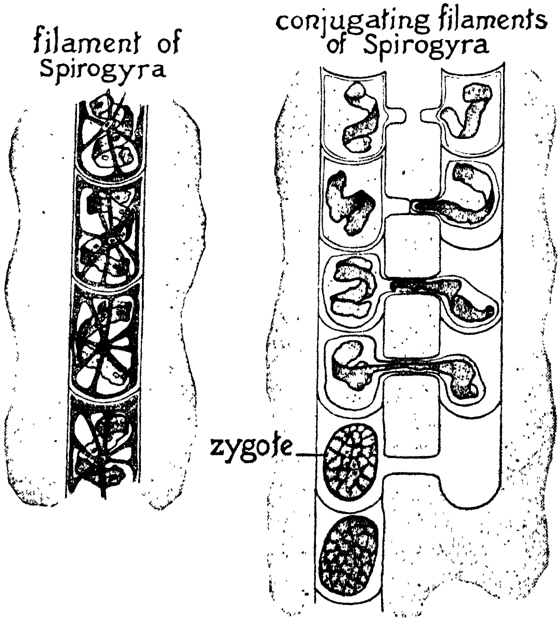
SEXUAL REPRODUCTION OF PLANTS

Conjugation

One of the leading forms of reproduction among certain lower plants and animals is *conjugation.* We may think of conjugation as the union of two cells or gametes neither of which may be distinguished as male or female. In general, it corresponds to fertilization, which takes place principally among higher forms of life. In fertilization the uniting cells (egg and sperm) are unlike in form and structure. In conjugation, on the other hand, so far as scientists have been able to discover thus far, the uniting cells are alike.

Conjugation illustrated by Spirogyra. We have learned two ways by which Spirogyra reproduces asexually; namely, cell division and vegetative multiplication of parts. Strange to say, this threadlike plant reproduces also by conjugation. The accompanying illustration shows the cells of two strands of Spirogyra lying near each other in the water. These cells send out tubelike projections from their cell walls. When the projections meet, the walls between them break down and a conjugation tube is formed between the cells. Then the entire contents of one cell passes into and mixes with the contents of

SPIROGYRA REPRODUCING BY CONJUGATION

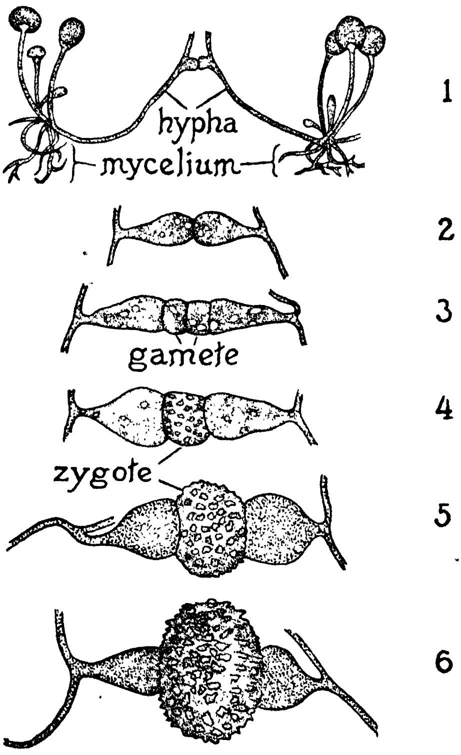


The text explains how conjugation of Spirogyra takes place.

the other cell, forming a *zygote*. As the zygote ripens, it forms a thick, hard, dark wall around itself, and is said to be in a resting stage. Thus equipped, it lies on the bottom of a pond until conditions for growth are favorable. Then it becomes active, cell division takes place, and a new plant develops.

How the black mold reproduces by conjugation. Black mold, which reproduces by spores and by vegetative stolons, also reproduces by conjugation. In this process two hyphae from a mycelium send out projections. These projections meet, enlarge at the tips, and are cut off from their original cells. The resulting zygote develops a thick, black, rough wall. When it germinates, a new mold plant is produced.

STEPS IN THE CONJUGATION OF BLACK MOLD



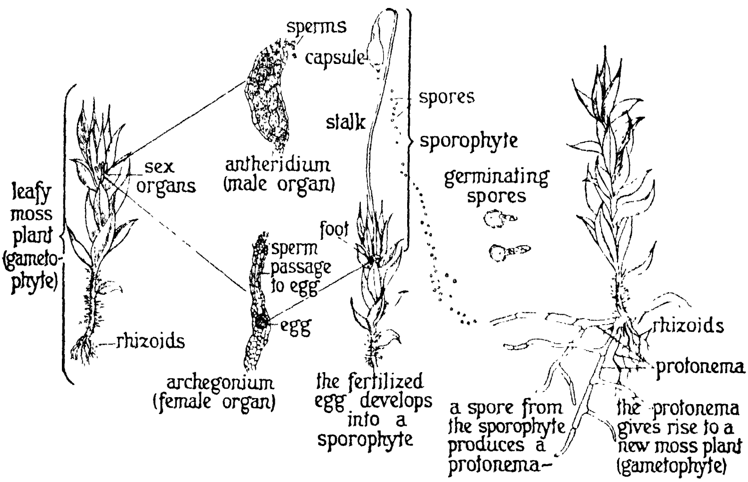
1. Protruding hyphae come into contact.
2. The points of contact enlarge.
3. Special cells called gametes develop.
4. The walls between the gametes dissolve and the gametes unite to form a zygote.
5-6. The zygote has a thick coat which protects it from unfavorable conditions in the environment. Under favorable conditions it will germinate and produce a new plant.

Alternation of Generations

Some plants, such as ferns, which are discussed in Unit Seven, employ both asexual and sexual methods of reproduction one after another. Such a change from one form of reproduction to the other in regular order is known as *alternation of generations*. Mosses present another excellent example of alternation of generations. These plants are doubtless familiar to us because they may be found almost everywhere. In some shady woods and bogs they become so abundant that they produce carpet-like growths on every hand. We shall now study a moss in detail.

The life cycle of a moss plant. A moss plant consists of rhizoids, an upright stem, and leaves. At the tip of the stem at certain times clusters of male and female sex organs appear. The female organs, or *archegonia* (är′kē-gō′nĭ-ȧ), are flask-shaped and develop eggs, or female gametes. The male organs,

LIFE CYCLE OF THE MOSS PLANT



This illustration presents all the steps in alternation of generations. Can you trace the complete cycle from the sexual through the asexual and back to the sexual again?

antheridia (ăn′thĕr-ĭd′ĭ-ȧ), are club-shaped and develop numerous sperms, or male gametes. Since the moss plant produces gametes, it is called a *gametophyte* (gȧ-mē′tō-fīt).

In the drawing above we can see the egg (female gamete) in the lower expanded part of the archegonium, and the sperms (male gametes) escaping from the antheridium. The sperms have two cilia that wave back and forth and enable them to swim in the moisture that collects on the plant. In their movement some of the sperms reach the neck of the archegonium and travel down to the egg at its base. Sperms may also be carried to the neck of the archegonium by a splashing raindrop. Only one sperm unites with an egg to form a zygote. In this case the male and female gametes are unlike; hence the process of their union is commonly known as *fertilization*.

At this point asexual reproduction begins. Nature does not free the zygote from the plant in which it develops, as it does in Spirogyra and the black mold (thallophytes). Instead, the zygote remains within the archegonium, where it divides and develops into an inconspicuous asexual structure called a *sporophyte,* so named because it bears spores. The sporophyte consists of a foot, stalk, and capsule, or spore case. The foot grows downward into the gametophyte or leafy moss plant, and the stalk and the capsule grow erect. Within the capsule numerous spores develop. When these spores are ripe, the lid drops off and they are scattered. If they happen to fall into favorable places, they germinate, producing threadlike structures called a *protonema* (prō′tȯ-nē′mȧ). Buds then appear on the protonema, which develop into new leafy moss plants, gametophytes. This completes the life cycle, including an alternation of a sexual gametophyte generation with an asexual sporophyte generation, or, briefly, an alternation of generations.

The Life Cycle of a Flowering Plant
Pollination and Fertilization

Thus far in this unit various forms of asexual and sexual reproduction have been presented. Insofar as possible these have been placed in a graded sequence from cell division (lowest form of asexual reproduction) to fertilization (highest form of sexual reproduction). A perfect sequence from the lowest to the most complex cannot be arranged because, as already pointed out, some plants reproduce by two or more methods.

Seed plants rely primarily on reproduction by fertilization, or the union of unlike gametes, the egg and the sperm. These plants are of two types, *angiosperms* (ăn′jĭ-ȯ-spûrmz) and *gymnosperms* (jĭm′nȯ-spûrmz). In angiosperms, or the so-called flowering plants, the seeds are inclosed in ovaries, whereas in gymnosperms they are said to be "naked." The life cycle of the pine, a gymnosperm, including reproduction by fertilization, is presented in Unit Seven. We shall now study the life cycle of a typical angiosperm.

How reproduction takes place in a typical flowering plant. The following are the principal steps involved in the reproduction of a typical flowering plant. As we study these steps, we should refer to the illustration on the following page.

Step No. 1. A typical flower, as the diagram shows, has several stamens and a pistil. These are the organs of reproduction. The tip of a stamen is called an anther, and the tip of a pistil, the stigma. Pollen grains form within the anthers and escape when they are ripe. These are the male gametophytes, and if reproduction is to take place some of them must be transferred from the anthers to the stigma of the pistil. Such a transfer of pollen, or male gametophytes, is called *pollination.* When the pollen grains pass from the anthers to the stigma of the same flower, the transfer is called *self-pollination.* When they pass from the anthers of one flower to the stigma of another flower, the transfer is called *cross-pollination.*

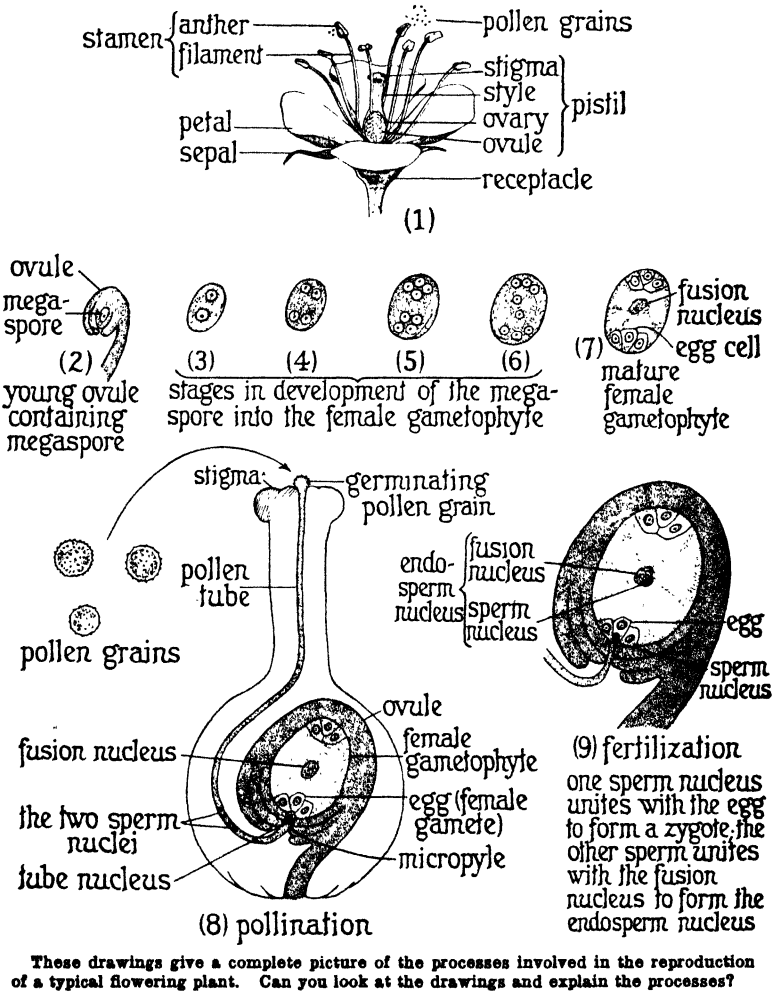
Step No. 2. Diagram 1 shows the position of the ovules in the ovary of the pistil. While the pollen is ripening, many changes are taking place in these ovules, as shown in diagrams 2 to 7. Each ovule contains one enlarged cell with a nucleus. This cell is called the *megaspore* (mĕg′ȧ-spōr′).

Steps No. 3, 4, 5, and 6. These steps show successive stages in the growth and development of the megaspore preparatory to the formation of the female gametophyte or embryo sac. The nucleus breaks up into eight nuclei. In step No. 6 three of the nuclei of the megaspore cell arrange themselves at each end of the cell, and two take a central position.

Step No. 7. Cell walls now divide the megaspore into seven cells. Each cell has one nucleus, except the large central cell, which has two that unite to form a *fusion nucleus.* One of the cells at the end of the gametophyte is called the *egg* or *female gamete.* The complete structure is called the *mature female gametophyte.*

Step No. 8. The stigma is covered with a sticky secretion that holds the pollen grains when they alight and provides moisture that enables them to grow. Each pollen grain develops a pollen tube that grows down the style of the pistil

REPRODUCTION IN A FLOWERING PLANT



These drawings give a complete picture of the processes involved in the reproduction of a typical flowering plant. Can you look at the drawings and explain the processes?

to the *micropyle*, or opening, of the ovule. The tube contains two sperm nuclei and a tube nucleus.

Step No. 9. When the pollen tube reaches the female gametophyte, it discharges the two sperm nuclei. One sperm nucleus

(male gamete) now enters the egg (female gamete) and unites with its nucleus to form a one-celled zygote. This zygote next divides and subdivides to form an *embryo*, a tiny new plant. The other sperm nucleus unites with the fusion nucleus in the female gametophyte to form the *endosperm nucleus*, which is now called the *endosperm cell*. From this cell endosperm tissue develops, which serves as food for the developing embryo. The wall of the ovule now hardens and temporarily stops the growth of the embryo. In this stage the ovule is called a *seed*. It will remain inactive until it finds favorable conditions for growth. If such conditions as temperature, moisture, and chemical content of the soil are not conducive to growth, the ovule will die after a certain period of time.

When cross-pollination is necessary. It is difficult and often impossible for many flowering plants to pollinate themselves. This difficulty may be caused by any one of a number of conditions. Differences in the length of the stamens and pistils may make cross-pollination necessary. Some flowers have short styles and long filaments, and others have long styles and short filaments. Self-pollination is best accomplished when pistils and stamens are about the same length. Cross-pollination is necessary also when the ovules and pollen on the same plant do not ripen at the same time. Usually the ovules ripen first; hence the pollen must come from the flower of another plant that has ripe pollen, as in the geranium.

Some flowers lack either stamens or pistils and are said to be *imperfect*. The willows and cottonwoods and some of the ashes and maples have imperfect flowers. All such flowers, of course, must be cross-pollinated.

Cross-pollination is accomplished primarily by wind, water, or animals. The pollen of such plants as trees and grasses is carried by the wind, and that of certain aquatic plants is carried by water. Among the insects that carry pollen are bees, wasps, butterflies, moths, and various kinds of flies that seek nectar. A few comparatively larger animals that visit flowers, such as hummingbirds, bats, and occasionally snails, also help considerably in cross-pollination.

Do Seed Plants Have an Alternation of Generations?[1]

Perhaps, while we have been studying the sexual reproduction of flowering plants, we have wondered whether they also carry on asexual reproduction. In other words: Do they have an alternation of generations? The answer is that they do, but the process is complex and difficult to understand.

All flowering plants, including trees, shrubs, and herbs, are leafy sporophytes. They produce two kinds of spores—*microspores* (mī′krō-spōrz) and *megaspores* (mĕg′ȧ-spōrz). The microspores are the pollen grains in their early stages before they leave the anthers. It is in these grains that the male gametophytes develop. The gametophytes are very small, being microscopic in size. The megaspores, which are located in the ovules, develop into the female gametophytes. When the sperms of the male gametophytes and the eggs of the female gametophytes unite, leafy sporophytes develop.

Thus the gametophyte plays a rôle of varying importance. In the moss plant it is the conspicuous part. In the fern plant it is second in importance to the leafy sporophyte. In seed plants it is microscopic, the leafy sporophyte being still more important as a full-grown tree, shrub, or herb.

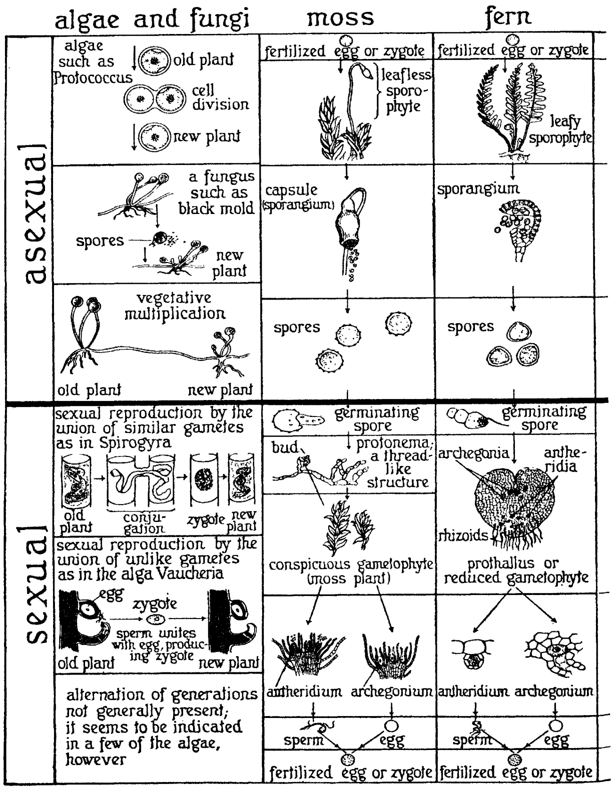
The Complete Picture of the Reproduction of Plants

Phylum (Arranged from Lowest to Highest)	Characteristics	Examples Selected to Illustrate Reproduction of the Phylum
1. Thallophytes	Simplest plants; no true stem or leaves	Algae—Protococcus, Spirogyra Fungi—bacteria, yeasts, molds
2. Bryophytes	Conspicuous gametophytes; no leaves on sporophytes; no vascular system	Liverworts—Marchantia Mosses—pigeon wheat
3. Pteridophytes	Reduced gametophytes; conspicuous sporophytes with vascular system	Ferns
4. Spermatophytes	Inconspicuous gametophytes; large leafy sporophytes; reproduction by seeds	Gymnosperms—pines Angiosperms—typical flowering plants with inclosed ovaries

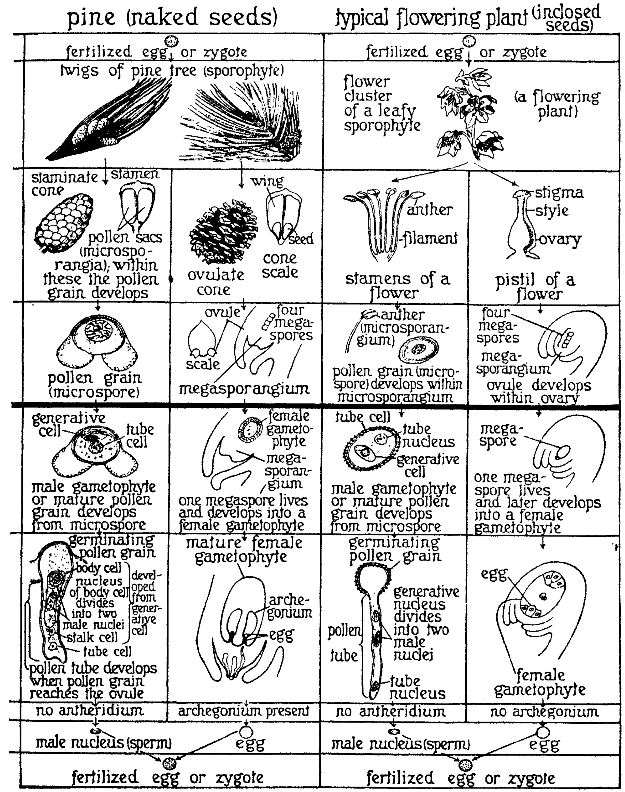
A condensed story of how these phyla of plants replenish the world with their kind is given in picture form on pages 590–591.

[1] *To the teacher:* If this topic seems too difficult, it may be omitted without injury to the unit as a whole. It is included for those who wish a rather complete picture of reproduction in flowering plants.

CONDENSED STORY OF HOW PLANTS REPRODUCE



Read the text carefully in connection with your study of this chart.



The chart gives a complete picture of reproduction in plants.

Problem 2. How do animals replenish the world with their kind?

Contrary to what is commonly believed, the reproduction of animals practically parallels that of plants. In other words, we find both asexual and sexual methods.

ASEXUAL REPRODUCTION OF ANIMALS

Production of new animals by cell division. The one-celled animals (Protozoa) are formed by a division of parent cells into two equal parts. Among the one-celled animals are the amoeba, Paramecium, Vorticella, and stentor, whose life histories are given in Unit Seven. A study of these histories will give a very clear understanding of cell division as it occurs in animals.

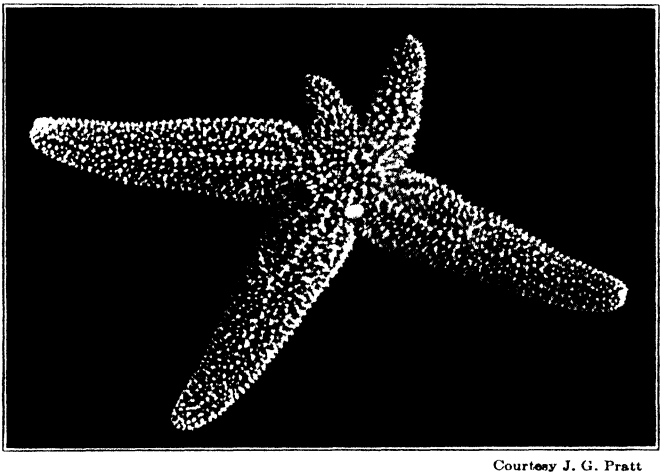
Production of new animals by means of spores. Some of the one-celled animals, Sporozoa, in certain stages of their life cycle, reproduce by spores. The microbe that causes malarial fever (*Plasmodium malariae*) is an example. The illustration on page 112 shows how the spores are formed.

Production of new animals by means of budding. The budding processes of the sponge and hydra are explained in Unit Seven, pages 347 and 349. These animals illustrate the reproductive process by budding as it occurs among such low forms of animal life. A portion of the body of a parent merely pushes outward, enlarges, and finally breaks away as a new individual. Reproduction of the sponge and the hydra, however, is not limited to budding, as these animals also reproduce sexually.

Production of new animals by means of "vegetative" regeneration. Some animals show evidences of vegetative multiplication similar to plant multiplication by means of cuttings and runners. This means that in the case of certain animals a detached part of the body will be replaced or even develop into a full-grown organism. The starfish, for example, shows great powers of regeneration. If it loses an arm, it grows a new one. If its body becomes broken into halves, under

favorable conditions it may produce two new individuals, each half growing independently of the other. The fresh-water hydra, when broken into several parts, will regenerate into as many new individuals. If the earthworm is cut into two parts, each part will grow into a new individual. The crayfish can regenerate any of its appendages, such as legs, claws, and antennae. The salamander and certain lizards can regenerate their legs and tails.

THE LOSS OF AN ARM LITTLE WORRY TO A STARFISH



Courtesy J. G. Pratt

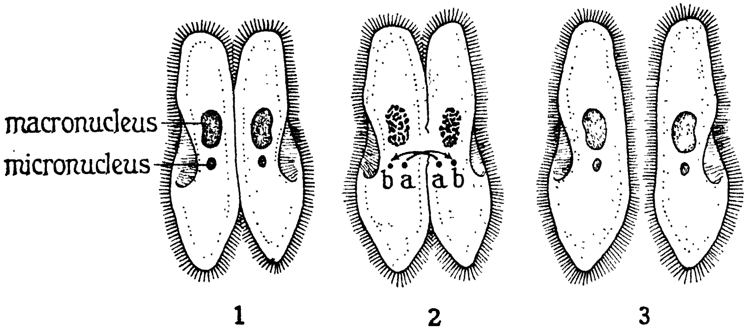
If a ray, or arm, is broken off, the starfish regenerates a new one. Note the two new arms which are growing on the creature shown above.

SEXUAL REPRODUCTION IN ANIMALS

Alternation of Generations in Animals

Although alternation of generations extends from the lowest to the highest forms of plants, it does not commonly occur among animals. In fact, it is almost limited to the lowest forms of animals. The life cycle of Obelia is a specific example of alternation of generations among animals. The Obelia belongs to the phylum coelenterates (sē-lĕn′tĕr-āts), animals which have body cavities, the same opening serving for intake of food and excretion of wastes. (See page 301.)

REPRODUCTION BY CONJUGATION IN ANIMALS—PARAMECIA



1. Two Paramecia meet and pair. (In conjugation the uniting cells are alike.)
2. The macronucleus shatters; each micronucleus divides into four parts; two of these parts live. Part (a) of one Paramecium fuses with (b) of the other.
3. The macronucleus and micronucleus of each Paramecium are rebuilt from the two micronuclei that fused.

Conjugation

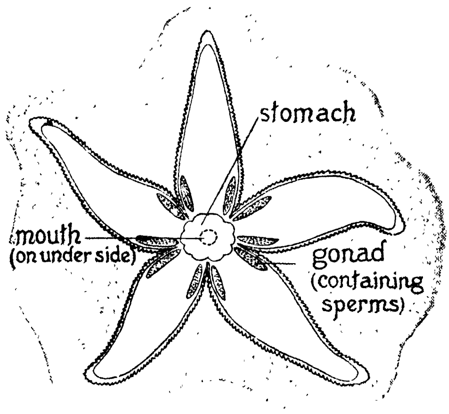
A fountain of youth for Paramecia. Paramecia ordinarily reproduce by cell division. Occasionally, however, they conjugate, that is, reproduce by the union of two like cells. It is uncertain why this process occurs. One accepted explanation is that as they become old they lose their ability to divide and resort to conjugation. Two Paramecia then come together and exchange parts of their micronuclei, after which they separate. This process seems to rejuvenate them, and as a result they carry on cell division again.

Fertilization in Animals

A bisexual animal—the sponge. The sponge produces both eggs and sperms within its body. The sperms usually mature before the eggs, and are discharged into the water. By means of cilia they swim to another sponge and fertilize its eggs. An animal that produces both eggs (female gametes) and sperms (male gametes) in this way is said to be *bisexual*. Reproduction in this form is limited to certain groups of the invertebrates. Other animals having both male and female reproductive organs in the same individual are the hydra and the earthworm, both low forms of life.

A unisexual animal—the starfish. In the higher types of animals, individuals are of only one sex and are said to be *unisexual.* This means that the *ovaries,* or egg-producing structures, occur in the body of one animal and the *testes* (tĕs′tēz), or sperm-producing structures, occur in another. Both ovaries and testes may be spoken of as *gonads* (gŏn′ădz). One of the most interesting examples of a unisexual animal is the starfish, the reproductive organs of which are shown in the illustration above.

A CROSS SECTION OF THE MALE STARFISH SHOWING GONADS



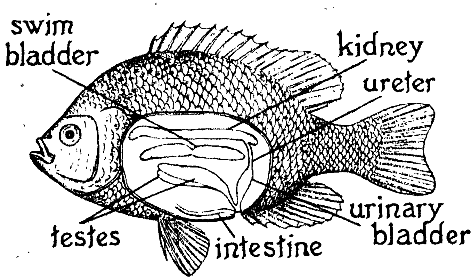
The female starfish is similarly formed except that the gonads (egg-producing structures) are much larger.

Reproduction of the fish. The reproductive organs of the fish are somewhat highly developed, the sexes, of course, being separate. The illustration on the following page shows the organs of a male. These include two testes and a definite outlet for sperms. The organs of the female include two ovaries which extend the length of the abdominal cavity. An interesting development in the fish is the comparatively close relationship of the excretory (ĕks′krē-tō-rĭ) organs of the urinary tract (kidney, bladder, and the ureters [ū-rē′tẽrz], the tubes that convey urine) with the organs of reproduction. In fact, the urinary bladder and the gonads have the same excretory opening. Thus we find the beginning of a combined urinary and reproductive tract. Such a combination is called a *urinogenital* (ū′rĭ-nō-jĕn′ĭ-tăl) *tract.*

Nearly all fish are *oviparous* (ō-vĭp′ȧ-rŭs), which means that they lay eggs. These eggs are called *spawn;* hence the process of laying them is called *spawning.* At a certain time or times of the year the female selects a suitable place for depositing

her eggs. Usually she chooses a place where the water is quiet, shallow, and warm. Then, too, she seeks a place where there will be plenty of food for the young. Some fish travel great distances to spawn, as does the salmon that travels hundreds of miles up the Columbia River until she comes to suitable beds of gravel. Here she spawns and deposits

REPRODUCTIVE ORGANS OF A MALE FISH



The fish has a urinogenital tract. The sperms are produced in the testes of the male, shown in the above illustration, and the eggs in the ovaries of the female.

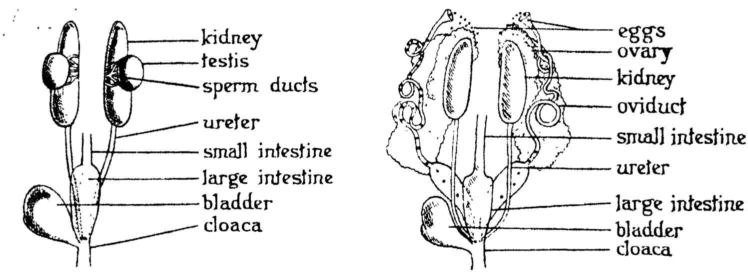
hundreds of eggs on the bottom. The eggs are then fertilized by *milt* (sperms) which the male releases as he swims about.

Although fish lay many eggs, only a comparatively small number are fertilized and grow into new individuals. This is because many eggs are consumed by animals or otherwise destroyed and because fertilization depends upon a chance meeting with sperms. So important is spawning to the preservation of many species that various states have passed laws that prohibit angling during the spawning season. Then, too, many states and the federal government have established fish hatcheries to insure sufficient breeding of certain species. In some of these hatcheries methods have been devised for fertilizing the eggs artificially.

A few fish are *viviparous* (vī-vĭp′ȧ-rŭs); that is, their eggs are fertilized within the reproductive tract of the female, and the young are born alive. The tropical "guppy" (the rainbow fish) commonly sold in pet stores is an interesting example.

Reproduction of the frog. In the frog there is a still closer relation between the urinary tract and the reproductive tract than in the fish. The following illustrations show how closely the two tracts are related. The eggs of the frog

REPRODUCTIVE ORGANS OF A MALE AND FEMALE FROG



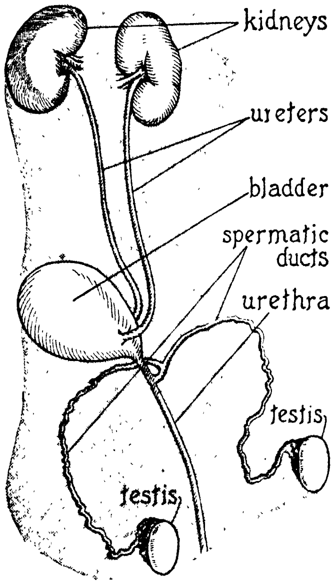
Notice in each case that the urinary and reproductive tracts are closely related. Which organs belong to the urinary tract alone? Which belong to the reproductive tract?

are laid in ponds or other bodies of shallow water in early spring. They are formed in the ovaries and move down the oviducts to an enlarged cavity where they accumulate before reaching the *cloaca* (klō-ā′kȧ). Then they are laid in large numbers. Before leaving the body, they take on a jelly-like covering which swells when they reach the water. This jelly-like covering holds them together and enables them to cling to plants. The eggs are fertilized by sperms that form in the testes of the male, and pass down the urinary tract.

As soon as fertilization takes place, each egg begins to grow by cell division. Within a few days a tiny tadpole breaks its jelly-like covering and wriggles its way out much as a chick hatches from an egg. This tadpole then attaches itself to a water plant or some other support, where it remains for a week or ten days, then breaks loose and begins to swim. The story of how it changes into a frog is reserved for Unit Twelve.

Reproduction of the mammal. Practically all mammals are viviparous; that is, they bear their young alive. In fact, this

URINOGENITAL TRACT OF A MALE MAMMAL

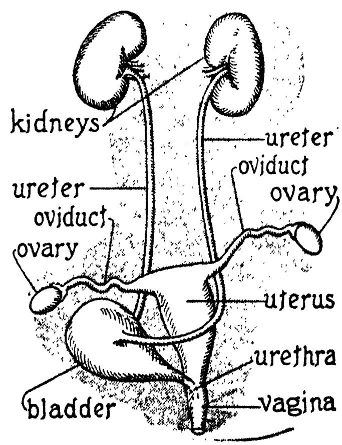


The testes produce the sperm or male cells, which are necessary for fertilization.

is one of the leading features that distinguishes them from other animals. A notable exception is the duckbill or platypus, which is found in Australia, described in Unit One. This bird-like animal lays eggs but possesses milk-secreting glands for nourishing its young.

The accompanying diagrams illustrate the reproductive organs of a typical mammal. Sperms, produced in the testes of the male, pass into the urethra or urinary outlet of the bladder, from which they leave the body. Eggs, produced in the ovaries of the female, move down to a cavity in the lower part of the oviduct.

URINOGENITAL TRACT OF A FEMALE MAMMAL



The ovaries produce the eggs or female cells which, after fertilization, produce the young.

After fertilization, they attach themselves to the walls of the oviduct, where they develop into new individuals. During the period of development they derive all their nourishment from the mother through the region of attachment. Then, when the development is complete, the individuals break contact with the mother and are born. The period of development varies with different animals.

Organisms That Have Both Sexes—Hermaphroditism

The animals we have just been studying are unisexual, but others, as we have learned, contain both male and female organs and consequently are bisexual. Animals that contain both organs of sex are called *hermaphrodites* (hẽr-măf′rŏ-dīts). The degree of hermaphroditism (hẽr-măf′rŏ-dīt-ĭsm) varies greatly. Some animals, such as tapeworms, flukes, and other parasites, fertilize their own eggs, but others, such as earthworms, snails, and sponges, must exchange sperms before fertilization takes place. In this way the sperms of one organism fertilize the eggs of another.

Organisms Produced from Unfertilized Eggs Parthenogenesis

Another unusual departure from the ordinary reproductive methods is *parthenogenesis* (pär′thē-nŏ-jĕn′ē-sĭs), the development of an egg into a new individual without fertilization. This occurs commonly in the algae and fungi, but very rarely in the seed plants. In the animal kingdom it occurs among the rotifers, the lower crustaceans, and certain insects.

Some authorities claim that certain animals, such as snails, occasionally change their sex. The evidence, however, that this actually happens is somewhat meager, and if it does occur, we have yet to determine the cause.

Insects that reproduce without fertilization. Excellent examples of insects that reproduce without fertilization are the aphids (plant lice) and bees. Wingless female aphids hatch in the spring from fertilized eggs that have lived through the winter. They reproduce for many generations without having their eggs fertilized and, since the young are born alive, are viviparous. Finally winged females appear that migrate to other habitats. These winged aphids also reproduce without fertilization of their eggs. Thus several generations of winged and wingless forms may appear by parthenogenesis. Finally late in autumn perfect males and egg-laying females are produced. Fertilization then takes place and winter eggs are laid. The eggs then remain dormant until spring.

In the case of bees some of the eggs are fertilized and others are not. All the workers and queens develop from fertilized eggs, but the drones come from eggs that are not fertilized. In a hive of bees, as explained in Unit Ten, the queen lays the eggs and many of them—sometimes as many as two or three thousand a day. This accounts for the fact that a single hive may contain fifty or sixty thousand individuals. Each egg is laid in a separate cell. Some of the cells seem to be reserved for fertilized and others for unfertilized eggs. One of the drones that develop from the unfertilized eggs ultimately mates with a new queen, while the others are lost or driven from the hive. Thus we have the strange situation of a male developing from an unfertilized egg and producing sperms to help give life to females alone.

Parthenogenesis from artificial stimulation. If the eggs of certain animals are exposed to electrical, chemical, or mechanical stimuli, they may be induced to develop without the aid of sperms. The larvae of certain echinoderms, for instance, may be developed from unfertilized eggs placed in water of varying salt concentration. Unfertilized eggs of frogs may be developed after being pricked with a platinum needle. The young tadpoles, however, will be deformed.

Problem 3. How do plants and animals care for their offspring?

INSURING THE NEXT GENERATION

One of the best evidences that plants and animals make ample provision for the continuance of their kind is the large number of sex cells they produce. An orchid, for example, in one season may produce as many as 75,000,000 seeds. A tobacco plant in the same length of time may produce 500,000 seeds. The fish is a good illustration of an animal that is prolific (highly productive). The conger eel lays about 12,000,000 eggs in a season, the codfish about 10,000,000, and the flounder about 1,500,000. The number of sperms produced must be still greater, since many sperms fail to reach the eggs.

Even with all this abundant production of sex cells, only relatively few organisms live. If all the eggs of the codfish were to hatch and develop, the sea would soon be filled with codfish to the exclusion of every other form of life. As it is, however, only a small percentage of the 10,000,000 codfish eggs laid in a season actually develop into full-grown animals.

SLIGHT PARENTAL CARE SHOWN BY PLANTS

The reproductive structures of certain plants are so designed as to protect and insure the growth of new plants. The hard cell wall of some spores, for example, enables them to withstand unfavorable conditions. The pollination organs of many plants insure pollination. The endosperm of seed plants provides food for the tiny plant until it is able to make its own.

How Plants Disperse Their Seeds

The many different methods of seed dispersal used by plants tend to insure perpetuation of their kind. Seeds are scattered into so many habitats that they are almost certain to find favorable places in which to grow.

HOW THE SQUIRTING CUCUMBER DISPERSES ITS "YOUNG"

Courtesy *Book of Popular Science* by permission of the Grolier Society

When the seeds are ripe, they are hurled out through an opening which was formerly corked up by the stem.

The mechanical dispersal of seeds. Some plants disperse their own seeds through the action and structure of their seed pods (ripened ovaries). When these pods burst, they split open with such force as to hurl the seeds free from the plant. The pod of the wild bean, for example, splits violently into halves. Other plants that hurl their seeds are the squirting cucumber, the touch-me-not, the witch-hazel, and the violet. The bursting open of any seed pod is called *dehiscence* (dē-hĭs′ĕns).

Dispersal of seeds by the wind. Forceful dehiscence, as we can readily see, is not an effective method of scattering seeds very far. Wide dispersal is accomplished for some seeds through tufts or winglike projections that enable them to float through the air under the force of the wind. Familiar examples of seeds scattered in this way are the milkweed, cottonwood, pine, and Catalpa.

SEEDS IN FLIGHT

Hugh Spencer

The seeds of the milkweed have buoyant tufts that enable them to "ride" on the wind.

Dispersal of seeds by animals. Birds eat many small fruits, such as grapes and cherries. The seeds from these plants pass through their digestive tracts unharmed and germinate in widely scattered places. Birds also scatter other small seeds by means of the mud that adheres to their feet. Many seeds, like those of the cocklebur, stick to the fur of animals and are carried considerable distances before they fall on the ground and germinate.

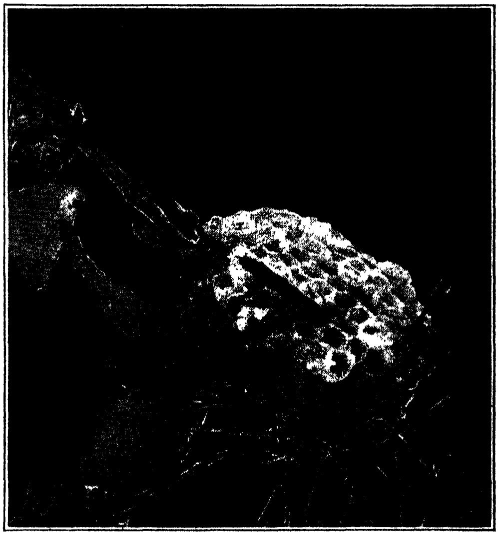
Dispersal of seeds by water. The seeds of some plants are provided with air chambers in their covering which enable them to float upon the water. Thus they may travel great distances, even as far as several thousand miles from the parent. The fibrous watertight shell of the coconut, for example, often floats from one tropical island to another.

PARENTAL CARE OUTSTANDING AMONG CERTAIN ANIMALS

It is in the animal kingdom that true parental care is manifested. Such care is most pronounced, of course, among the higher animals, although many lower animals, such as insects and spiders, show unusual interest in their young.

Parental care among insects. Many of the insects care for their young in the nests. In the hive of the honeybee certain "nursemaids" furnish secretions from their stomachs for feeding the developing larvae. Soldiers and guards also protect the young.

THE WASP A GOOD MOTHER



L. W. Brownell

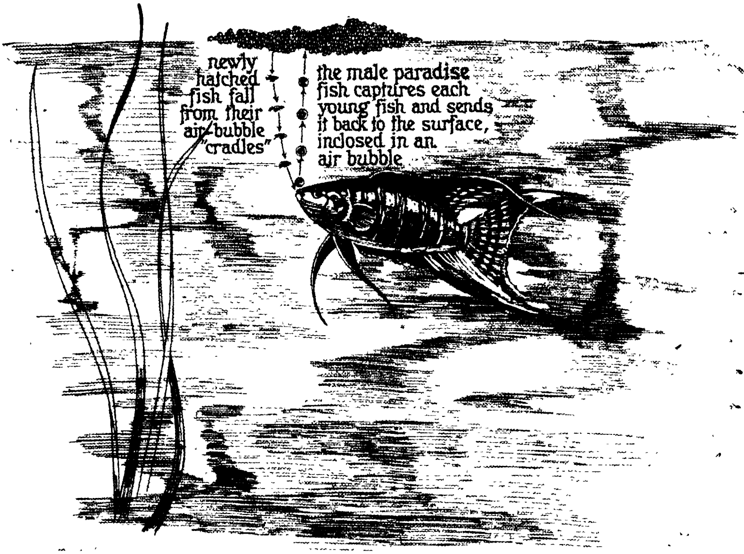
The wasps in this picture are crawling about over their nest to watch over their young.

The termites, or so-called "white ants," utilize special sections of their homes wholly as nurseries. When the colonies are disturbed and are in danger of destruction, the older termites heroically carry out the eggs and young and attempt to transport them to places of safety.

Parental care among crustaceans and fish. The crayfish is unusual among water animals in the care that it gives its young. The female carries her eggs about in *swimmerets.* Later she carries the young about in a similar manner.

As we advance to higher animals, we find that even the males of certain species take an active interest in parental care. A good illustration is found in the habits of tropical paradise fish. This tiny animal is often referred to as a "bubble

BLOWING BUBBLES NOT MERELY A GAME



The paradise fish is one of the most popular toy tropicals that may be kept in the home aquarium. It is very hardy and withstands lower temperatures than most tropical fish. The male blows bubbles for the purpose of keeping the eggs and the young fish afloat.

blower" because prior to the spawning period the male blows a froth of bubbles on the water. The female then deposits eggs in the bubbles. The male fertilizes the eggs and from that time takes complete charge of the situation.

An aquarium provides an excellent opportunity to watch the behavior of the male paradise fish as he goes about his parental duties. After the female lays her eggs, the male drives her away and will kill her if she is not removed from the aquarium. Then he takes a position under the eggs and circulates the water about them by means of fin and tail movements. The purpose of this is to assure the eggs of a good supply of oxygen. As the young hatch they become heavy and tend to fall out of their air-bubble "cradles." The male, however, is continually alert and catches them as they fall. Then he blows some more bubbles and shoots them back to the surface of the water.

After a few days the young fish are able to swim about. The male then seems to feel that his offspring have an equal chance with all the other fish of his natural habitat and completely loses his parental affection. In fact, he becomes ferocious, and will devour the young unless he is removed from the aquarium.

Parental care among mammals. The mammals quite generally are devoted to their young. One of the most unusual illustrations of parental care is shown by the kangaroo, which is a devoted mother. The young kangaroo when born is only about an inch long and is so helpless and undeveloped that it seems almost jelly-like in structure. This tiny creature is cared for in an external abdominal pouch on the body of the mother. (See the illustration on page 676.)

Most of us are familiar with the parental care of dogs for their young. They stand guard over them, hiding them if possible and feeding them at frequent intervals. So strong is the mother instinct in some animals that they lavish their care upon the young of other animals as generously as upon their own offspring. Collie dogs, for example, have frequently been known to mother a litter of young kittens when the need has

PARENTAL CARE AMONG THE WILD FOLK

Lynwood M. Chace

If danger threatens, a mother raccoon will carry her young to a place of safety.

arisen, and cats will mother young rabbits. Many other examples of the parental instinct might be cited to show how well nature provides for the young.

The period of infancy and childhood in man is longer than that of most other animals. Furthermore, human babies are more helpless than the young of most other animals. Since these things are true, man devotes a great deal of attention to his children as they develop into adults. He provides them with food, clothing, and shelter over a long period of years. He provides them with schools so that they may be trained to become useful citizens and to make the best use of their environment. He helps them to get a "start in life" or secure a place in the world whereby they may become self-supporting. In short, he makes great sacrifices in order that they may receive the best that life has to offer. We are not surprised, therefore, to find in the human family the highest type of parental traits.

SUGGESTED ACTIVITIES

I. Self-Organization Summary

A. Reproduction in Plants
   1. Explain briefly three methods of sexual reproduction, using a plant to illustrate each method.
      Give the stages in the life cycle of a moss plant and explain what is meant by alternation of generations.
   3. Describe reproduction by conjugation as it occurs in Spirogyra.
   4. Mention the steps involved in the pollination and fertilization of a seed plant.

B. Reproduction in Animals
   1. Prepare a summary of animal reproduction similar to that given for plants on pages 590–591.

C. The Care of Young by Plants and Animals
   1. Illustrate by means of seeds the methods used by plants for the dispersal of seeds.
   2. Explain how various animals give parental care to their young.

II. Laboratory Study

The laboratory work for this unit may properly include the making of dissections and the use of microscopic slides and lantern slides. Below is a list of specimens that may be easily obtained for study.

A. Plants

1. Stained slides of the tips of onion roots—to show mitosis
2. Black mold—to show spores
3. Spirogyra—to show conjugation
4. Vaucheria—to show sexual reproduction among the algae
5. Moss plant—to show alternation of generations
6. Fern—to show alternation of generations
7. Flowers—to show reproduction of seed plants

B. Animals

1. Paramecia—to show cell division and conjugation
2. Sponge—to show budding
3. Obelia—to show alternation of generations
4. Starfish—to show sex organs and regeneration
5. Fish—to show sex organs
6. Frog—to show sex organs

C. Collections

1. Specimens illustrating various methods of reproduction. These may be arranged in specimen boxes and bottles according to their nature.
2. Seeds. These may be mounted in groups according to similarities and differences.
3. Seed pods. These should be grouped according to their method of dispersal.

III. Display Posters

A. Life cycles. These should cover the various life cycles studied in the unit. Each should be drawn and explained on a separate chart.

B. Mounted pictures of animals showing parents and their offspring

C. Mounted pictures of plants resulting from various forms of reproduction

IV. Special Reports

A. The reproduction of plants or animals not described in the unit
B. Other animals that care for their young
C. Interesting methods of pollination
D. Grafting as a means of reproduction among plants

REFERENCES[1]

1. Bull, Raymond C., and Thomas, Stanley. *Freshman Hygiene.*
   a. The male reproductive system, pp. 211–216
   b. The female reproductive system, pp. 217–226
2. Diehl, Harold S. *Healthful Living.*
3. Guttmacher, Alan Frank. *Life in the Making.*
4. Kinberg-von Sneidern, Dr. Julia, and Sundquist, Dr. Alma. *Sex Hygiene.*
   A book written especially for the enlightenment of high-school students
5. Kirkpatrick and Huettner. *Fundamentals of Health.*
   a. Genetics and human inheritance
   b. Sex and reproduction
6. Matheny, William A. *Seed Dispersal.*
   a. Bird distributors, pp. 7–36
   b. Wind dispersal, pp. 36–58
   c. Water dispersal, pp. 58–70
   d. Insect dispersal, pp. 70–75
   e. Bur-like seeds and fruits, pp. 75–86
   f. Explosive and shaker fruits, pp. 86–100
7. Parshley, H. M. *Science of Human Reproduction.*
8. Robbins, Wilfred W., and Pearson, Helen M. *Sex in the Plant World.*
9. Transeau, Edgar Nelson. *General Botany.*
   a. The reproduction of algae, pp. 441–465
   b. The reproduction of moss, pp. 465–476
   c. The reproduction of pteridophytes, pp. 477–494
   d. The reproduction of seed plants, pp. 503–545
10. *Book of Popular Science, The.*
   a. Propagation methods in plants, Vol. 5, pp. 1457–1464
   b. Life reproduces itself, Vol. 2, pp. 613–622

[1]The pages listed here are those found in the editions indicated in the alphabetical list of references given at the end of this book.

11. *Compton's Pictured Encyclopedia.*
    a. Nature's fancies in the world of eggs, Vol. 4, pp. 192–193
    b. The life of a flower, Vol. 5, pp. 121–127
12. *New Wonder World, The.*
    a. How plants travel, Vol. 10, pp. 22–31
    b. Nature's nurseries, Vol. 10, pp. 111–121
13. *World Book Encyclopedia, The.*
    a. Methods of seed dispersal, pp. 6481–6483
    b. Methods of grafting, pp. 2886–2888

VISUAL AIDS

FILMS (16 mm.)

A. Y. M. C. A. Motion Picture Bureau, New York City.
   1. Seeds and Seed Dispersal. 1 reel, silent, $1.00 per day. Illustrates the processes of germination and propagation
   2. Fruits and Flowers. 1 reel, silent, $1.50 per day.

B. Bray Pictures Corporation, 729 Seventh Avenue, New York City.
   1. Reproduction in Higher Forms. 1 reel, silent, $35.00. Illustrates the principle of reproduction among fish, reptiles, birds, and men

C. Indiana University, Extension Division, Bloomington, Indiana.
   1. Social Hygiene for Women. American Social Hygiene Association. 1 reel, $1.00 per day.
   2. Venereal Diseases. 1 reel, $1.00 per day. Provides information of special interest to men

D. U. S. Department of Agriculture, Washington, D. C.
   1. In the Beginning. 2 reels, sound, free. Shows ovulation, fertilization, and early development of the mammalian egg

CHARTS

Series	*Titles*
A. J-K-Q Botany	Algae
B. Schmeil Botany	Fern
C. Johnson Elementary Anatomical Botany	Flower, Stamen, and Pistil
D. Pfurtscheller Zoölogy	Paramecium
E. Frohse Anatomical	Reproduction in Man

UNIT TWELVE

FROM FERTILIZED EGG CELLS TO INDEPENDENT ORGANISMS

SUGGESTIONS TO THE TEACHER

The purpose of this unit is to present some of the interesting stages through which organisms pass in their embryonic development. Biological content usually centers around life processes of adult forms of plant and animal life, including such related topics as hygiene and sanitation, and human physiology. As a result it passes over too lightly certain important processes that occur between the time of fertilization and the time when independent organisms come into being. Consequently we hope that the real importance of this unit will be recognized in rounding out a complete picture of life. Moreover, we hope that through its study students will be stimulated to a further study of embryonic life.

Like the preceding unit, this unit summarizes concepts presented in several of the earlier units. Care should be exercised not to let the presentation become too technical. It is imperative, then, that particular attention be given to devices for making the subject matter dynamic. Here again demonstration work, especially in the study of the embryological development of the corn and bean, will prove effective. Among animals the development of the tadpole is always interesting.

OBJECTIVES

I. Facts and principles

A. To study the elementary embryology of a few typical plants and animals

B. To develop a better understanding of the beginning of life

II. Attitudes

A. To appreciate how an independent organism develops from a fertilized egg

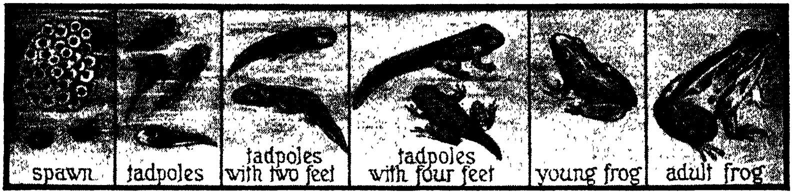
B. To develop an understanding of the relative importance of the embryonic stages of development

C. To gain pleasure in the use of the microscope in observing embryonic development

UNIT TWELVE

FROM FERTILIZED EGG CELLS TO INDEPENDENT ORGANISMS

HOW THE FROG GROWS UP



Note all the marvelous changes by which a gill-breathing tadpole is transformed into a lung-breathing frog — changes that constitute one of the miracles of nature.

FROM EGG TO TADPOLE TO FROG

PREVIEW

Have you ever watched a tadpole as it passed through the successive stages in becoming a frog? If you have not, you have failed to observe one of life's greatest mysteries. The little tadpole, as you know, looks more like a fish than like a frog. In fact, it behaves more like a fish, since it breathes through gills and swims about by the aid of its tail. It even has a two-chambered heart like that of a fish. Indeed, as you look at it, you see so little resemblance to a frog that you wonder how it can turn into one. Turn into a frog it does, nevertheless; and here are some of the changes it undergoes in the course of its marvelous transformation, or metamorphosis, as scientists express it. The gills disappear from the external parts, and lungs develop to take their place as organs of breathing; hind legs appear, and then front legs; the heart takes on an extra chamber; modifications occur in the digestive tract; and the long tail shrinks and is absorbed, growing smaller and smaller until it completely disappears.

Perhaps even more interesting than the metamorphosis from tadpole to frog are the changes that occur in the fertilized egg before the tadpole comes into being. Once people believed that the tadpole was actually in the egg when the egg was laid. Today, however, we realize that the tadpole develops through the process of mitosis. Doesn't it seem amazing that egg cells can begin to multiply, assume the shapes of various parts of an organism, and finally grow into the organism itself? Nevertheless, this is exactly what happens as the tadpole forms. From a tiny mass of protoplasm it emerges a fully developed organism with gills, eyes, and digestive tract and takes up an independent existence.

All organisms that reproduce by fertilized eggs must pass through an early period of growth somewhat similar to that through which the tadpole passes as it develops. The study of the early development of organisms is called *embryology*. In mammals this development takes place within the body of the mother before the young are born. In nearly all the lower animals the development takes place outside the body of the mother. In the seed plants embryology is concerned with the development of seeds.

Doubtless this brief description of the development of an egg into a tadpole has left many questions unanswered in your mind. You may want to know more of the details of embryology, or the process by which fertilized egg cells can actually build up by mitosis independent organisms possessing cells, tissues, and organs that have wide variations of form and function. It is to answer some of your questions that the following problems are submitted.

PROBLEMS

1. **How do plants change from fertilized eggs into new organisms?**
2. **What changes take place from the time when animal eggs are fertilized until the young are born?**

Problem 1. How do plants change from fertilized eggs into new organisms?

In Unit Eleven the story of pollination and fertilization is presented. In that unit we find that in the flowering plants two sperm nuclei enter into the fertilization process. One sperm nucleus unites with the egg nucleus to form a *one-celled embryo*. The other sperm nucleus unites with the fusion nucleus to form the *endosperm*, which serves as a food supply. Successive divisions of these two cells result in the enlargement of both embryo and endosperm. The covering, or the *ovule*, later becomes hardened and forms the *seed coat*, or *testa*. The ripened ovule with its contents is now called the *seed*, and the growth of the embryo is temporarily checked. It is at this stage that our new study begins. In other words, we shall consider how the embryo develops into a new plant.

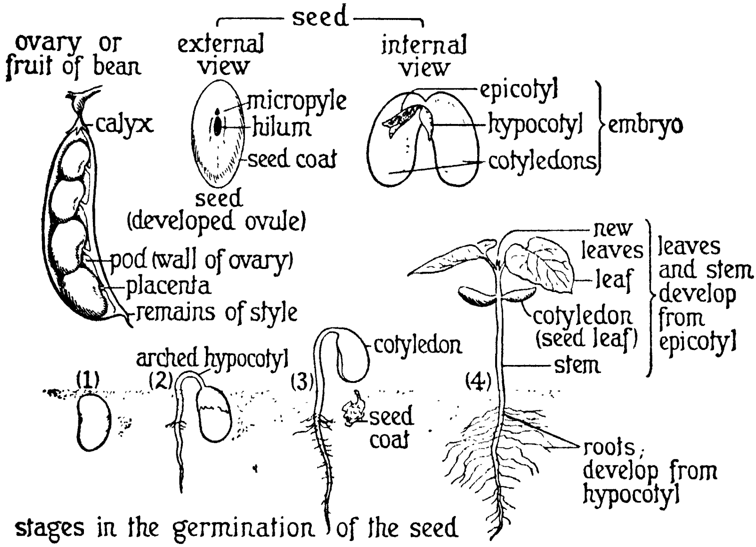
THE DEVELOPMENT OF THE BEAN EMBRYO

The inside of a bean seed. The very young bean seed consists of three parts: (1) a food supply, or endosperm, (2) an embryo, or tiny plant, and (3) a seed coat, or testa. The embryo also consists of three parts: (1) embryonic leaves, or *cotyledons*, (2) the rootlike structure below the cotyledons, or *hypocotyl* (hĭ′pō̆-kŏt′ĭl), and (3) the stem and leaves above the cotyledons, or *epicotyl* (ĕp′ĭ-kŏt′ĭl), sometimes called *plumule* (plo͞o′mūl). As the young embryo develops, the cotyledons absorb all the endosperm and become fleshy. Since the embryo has two cotyledons, the bean is placed in the group of flowering plants called *dicotyledons*. (See page 614.)

The outside of a bean seed. Looking at the bean seed from the outside, we see (1) the seed coat, (2) a scar called the *hilum* (hī′lŭm), which indicates the place where it separated from the seed pod or ovary wall, and (3) a tiny opening into the seed called the *micropyle* (mī′krō̆-pīl). It is through this tiny opening that the embryo first bursts from the seed.

Conditions under which seeds begin to grow. When the seed pods or ovaries are fully ripe, the seeds begin to scatter. If they fall into favorable habitats, they *germinate;* that is,

GROWTH FROM A FERTILIZED EGG CELL TO A NEW BEAN PLANT



This drawing shows the parts involved in the development of a bean embryo. Which parts will become the roots, which part the stem, and which parts the leaves of the new plant?

they begin to grow. The conditions or factors that affect germination are: (1) moisture; (2) temperature—a range between 52° Fahrenheit and 73° Fahrenheit being the most favorable; and (3) oxygen. Most seeds, with the exception of a few such as tobacco and blue grass, also germinate better in the dark. This may be explained by the fact that the embryo of most seeds possesses its own food supply and does not need sunlight for manufacturing more.

Beginning of growth in the bean seed. When a bean seed is planted in the soil, it immediately absorbs water, and the numerous cells of the embryo begin to divide. The hypocotyl enlarges and forces its lower part outward through the micropyle and downward into the soil to form roots. The upper part of the hypocotyl arches and lifts the cotyledons, or embryonic leaves, into the air. These then open so as to permit the epicotyl to emerge and the stem and leaves to develop. The

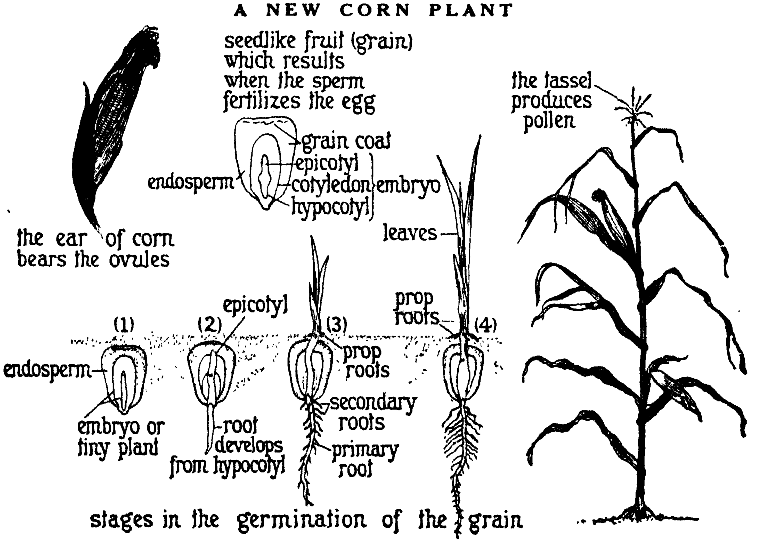
cotyledons do not remain as regular leaves, but gradually shrink as their stored food is exhausted. By this time, however, a few green leaves have developed, and the plant is now ready to manufacture its own food.

The Development of the Corn Embryo

It has already been pointed out that the bean is called a dicotyledon because its embryo contains two cotyledons. We shall next consider a plant that has but one cotyledon in its embryo. Such a plant is called a *monocotyledon*, a good example of which is corn.

The endosperm of corn, like that of the bean, serves as a storehouse for food and consists largely of starch. In fact, it makes up a large part of each grain or kernel. The cotyledon, on the other hand, is small, much smaller than those of the bean. The stages in the development of the corn embryo are shown in the following illustration.

GROWTH FROM A FERTILIZED EGG CELL TO A NEW CORN PLANT



This drawing shows the parts involved in the development of a corn embryo. Which parts will become the roots, which part the stem, and which parts the leaves of the new plant?

Problem 2. What changes take place from the time when animal eggs are fertilized until the young are born?

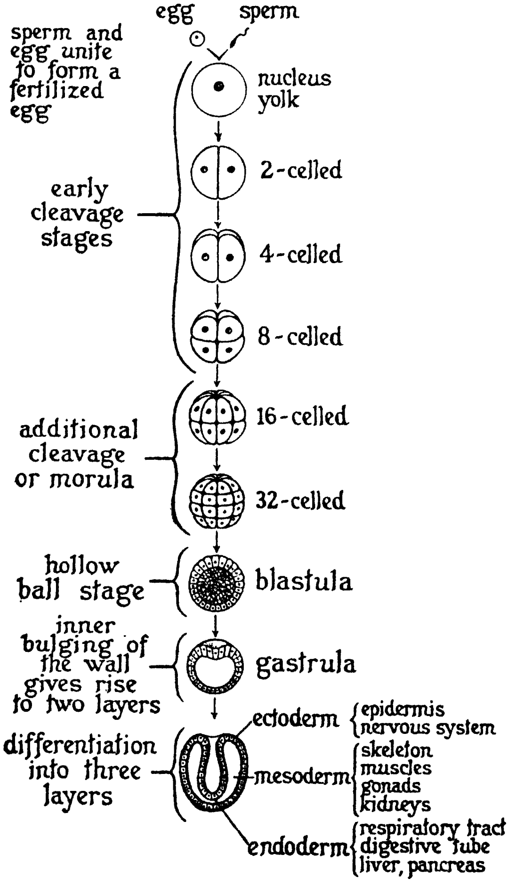
We have learned that flowering plants reproduce sexually and develop from fertilized eggs. Likewise, all animals that reproduce sexually develop from fertilized eggs. The process of sexual reproduction is of special importance because it is the method employed by all the higher forms of animal life.

Basically, the process of sexual reproduction is the same among animals as among flowering plants. When an egg has been fertilized, an embryo develops by means of cell division. At various points, however, the development of the animal embryo differs from the development of the plant embryo. Indeed, the development differs in some respects even among the various kinds of animals.

THE DEVELOPMENT OF THE FERTILIZED EGGS OF ANIMALS

After the egg cell of an animal has been fertilized, it begins to divide. The first division results in two cells, the second in four cells, the third in eight cells, and so on. Such a division is called *cleavage*. After a time the cells form a ball-like globular mass somewhat resembling a mulberry. Hence this stage is commonly called the *morula* (mŏr′o͝o-lȧ), which means "mulberry." The cells later arrange themselves in a single layer with a cavity in the center, resembling a hollow ball or sphere. This stage is called the *blastula* (blăs′ţ̈ū-lȧ). Further cell division results in a depression in one side of the blastula much like the hollow produced when a finger is pressed against a hollow rubber ball. This stage is known as the *gastrula* (găs′tro͝o-lȧ) or *double-layered* stage. On the outside of the gastrula is a layer of cells called the *ectoderm* and on the inside a layer called the *endoderm*. A third layer, called the *mesoderm* (mĕs′ō-dûrm), forms between the two. The three layers together produce the various organs of the body. The ectoderm produces the epidermis and the nervous system, and the mesoderm produces the skeleton, the muscles,

STAGES IN THE GROWTH OF A FERTILIZED EGG CELL OF AN ANIMAL



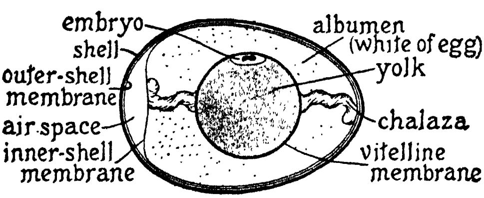
Multicellular animals develop their bodies through a complicated process of cell division. They begin, of course, as fertilized egg cells. The egg cells divide many, many times, after which organs and tissues begin to appear.

the kidneys, and the gonads. The endoderm produces the respiratory tract, the digestive tube, the liver, and the pancreas. Thus a single cell gradually produces various complicated organs, each with a special form and function. These and other central facts regarding the development of an animal embryo are shown in the illustration above.

THE DEVELOPMENT OF THE CHICK EMBRYO

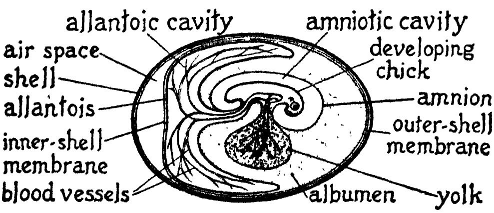
What happens within an egg. The vital part of a chicken egg is the yolk. As the yolk passes down the *oviduct* (ō′vĭ-dŭkt) of the female, it acquires coverings of *albumen* (white of the egg) and shell membranes. When the egg is laid, all the stages in the development cease until proper temperature is continuously applied.

THE PARTS OF A CHICKEN EGG



This illustration shows an egg at the time it is laid. The true egg includes only the central part.

THE PARTS OF A CHICK EMBRYO IN PROCESS OF DEVELOPMENT



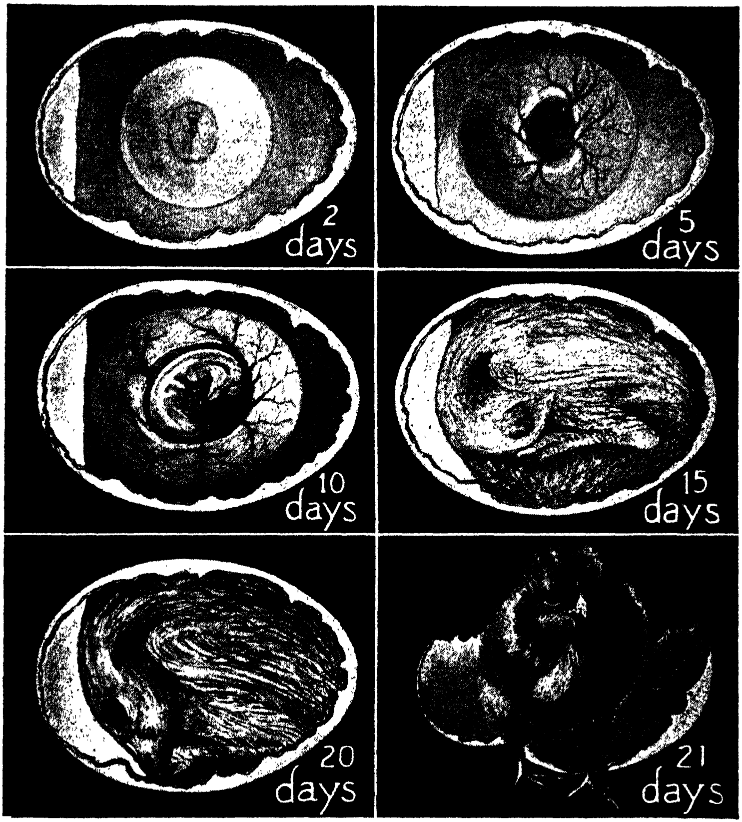
This illustration shows an egg after a period of incubation, when the embryo is well developed.

The upper illustration at the left shows what an egg is like when it is first laid. The true egg, or the yolk, is surrounded by a thin covering known as the *vitelline* (vĭ-tĕl′ĭn) *membrane.* Outside the yolk and vitelline membrane lies the albumen, or the white of the egg, twisted portions of which, the *chalazae* (kȧ-lā′zē), keep the yolk in place.

Late in the period of incubation, as shown in the lower illustration, a membrane known as the *amnion* (ăm′nĭ-ŏn) forms around the embryo. Between the amnion and the embryo is the *amniotic fluid,* a liquid which protects the embryo from shock. Another protecting membrane, called the *chorion* (kō′rĭ-ŏn), surrounds the embryo and the amnion.

The most important organ in the development of the embryo is the *allantois* (ă-lăn′tō-ĭs), which lies between the amnion and the chorion. It is an outgrowth of the intestine and consists of a membrane bounding a cavity. Part of this membrane lies near an air space. The blood vessels of the allantois enable the embryo to secure oxygen and to release

HOW THE CHICK BEGINS ITS LIFE



The illustrations show what happens within a chicken egg while the fertilized egg is developing into a chick. All these changes take place within twenty-one days.

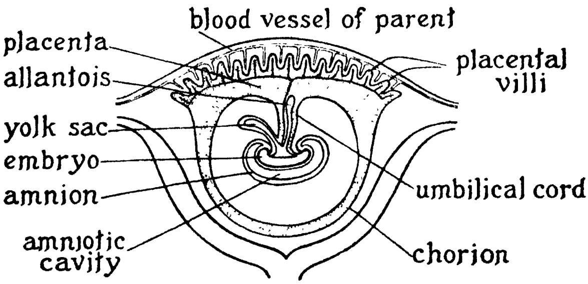
carbon dioxide. They also absorb albumen. The cavity in the allantois seems to act chiefly as a receptacle for excretions from the kidneys.

After twenty days the albumen and the food in the yolk sac are consumed. Then the membranes that assist the embryo in its development dry up. On the twenty-first day the shell of the egg cracks and the chick begins an independent life. Stages in the egg are shown above.

THE DEVELOPMENT OF THE MAMMALIAN EMBRYO

A parasitic existence. The development of the mammalian embryo is somewhat similar to that of the chick. The mammalian embryo, however, develops chiefly within the body of the female. The yolk sac of the embryo is very small and soon disappears. This makes it necessary for the embryo to receive nourishment directly from the body of the mother.

PARTS OF THE MAMMAL EMBRYO



How is the embryo protected against shock?

The nourishment is received through an absorbing region known as the *placenta* (plȧ-sĕn′tȧ) and a connection known as the *umbilical* (ŭm-bĭl′ĭ-kăl) *cord.* Otherwise the main structures are similar to those of the chick embryo, as shown above.

Blood vessels in the umbilical cord extend to the placenta, or absorbing region. Actual absorption takes place through tiny projections known as *placental villi* (vĭl′ī). Through these villi, food and oxygen pass by osmosis from the blood vessels of the mother directly to the embryo. Similarly, waste products from the embryo pass into the blood stream of the mother. Thus the embryo may be considered an independent organism living in a parasitic manner.

As pointed out in Unit Eleven, the young of mammals are usually born in a somewhat helpless condition. Since this is the case, they require nurture from the mother for varying lengths of time before they can begin an independent existence. Some young are much more active than others immediately

after birth. A newborn colt, for instance, is able to walk within a few hours, as are most of the other young raised upon farms. The babe of the human species, on the other hand, cannot walk for a great many months.

Somewhat related to the foregoing is the fact that a higher percentage of the young of higher mammals survive than of lower mammals. On the other hand, the lower mammals bear larger numbers of young than do the higher mammals. Thus nature seems to have adjusted the number of young according to the chances of living.

The time required for an embryo to develop, or the *gestation* (jĕs-tā′shŭn) *period*, varies with different animals. In general, larger animals require a longer period than smaller ones, as shown by the following table.

GESTATION PERIOD OF CERTAIN MAMMALS

Animals	*Months*	*Animals*	*Months*
Mouse	¾	Human being	9
Rabbit	1	Cow	9
Cat	2	Horse	11
Dog	2¼	Elephant	22

SUGGESTED ACTIVITIES

I. Self-Organization Summary

A. The Development of Plant Embryos
  1. List the external and internal parts of the bean seed. State the function of each part.
  2. Trace the development of the bean embryo from fertilized egg to independent plant.
  3. List the internal parts of a grain of corn. Give the function of each part.
  4. Trace the development of the corn embryo.

B. The Development of Animal Embryos
  1. Describe the metamorphosis of a frog.
  2. Trace the development of the chick embryo from fertilized egg to independent organism.
  3. Name the membranes of a chick embryo and explain the function of each.

4. Trace the development of the mammalian embryo.
5. Name the membranes of the mammalian embryo and explain the function of each.

II. Laboratory Study

A. Germinate some bean seeds and grains of corn by placing them between pieces of moistened blotting paper in a dark place. Dissect them so as to note the development of embryos at various stages.
B. Examine prepared microscopic slides of developing embryos. Do this from the standpoint of interest rather than for the purpose of learning technical detail.
C. Secure some frog eggs from a local pond or biological supply station and observe their embryonic development under the low-power lens of a microscope.
D. Incubate some chicken eggs and open one each day to note the successive stages of development.

III. Display Posters

A. Prepare charts showing the embryos of fish, amphibians, reptiles, birds, and mammals.
B. Draw diagrams showing the stages of development of a chick embryo.
C. Prepare sketches of the reproductive structures of various animals showing their relation to embryonic development.

REFERENCES[1]

1. Arey, Leslie Brainerd. *Developmental Anatomy.*
   a. Cleavage in lower fishes and amphibians, pp. 48–51
   b. Cleavage in higher fishes, reptiles, and birds, pp. 51–57
   c. Cleavage in mammals, pp. 57–63
   d. The formation of ectoderm and endoderm, pp. 34–36
   e. Origin of mesoderm, pp. 44–63
   f. Fetal membranes in reptiles, birds, and mammals, including man, pp. 64–104
   g. Age, body form, and growth changes, pp. 105–133
2. Davenport, Charles B. *How We Came by Our Bodies.*
   a. The beginning of body form, pp. 19–34
   b. How the genes work, pp. 137–185

[1]The pages listed here are those found in the editions indicated in the alphabetical list of references given at the end of this book.

3. Strain, Frances B. *Being Born.*
   a. Where the egg is made, pp. 16–27
   b. Where the sperm is made, pp. 16–27
4. Waddington, C. H. *How Animals Develop.*
5. *Book of Popular Science, The.*
   a. From fertilized egg cells to plants and animals, Vol. 3, pp. 893–903
   b. Food requirements of the embryo, Vol. 11, pp. 3609–3611
6. *Compton's Pictured Encyclopedia.*
   a. All about frogs and polliwogs, Vol. 5, pp. 207–209
   b. The development of the bean embryo, Vol. 2, pp. 65–66
7. *New Wonder World, The.*
   a. From seeds to independent plants, Vol. 10, pp. 102–106
   b. From egg to chick, Vol. 10, pp. 107–110
8. *World Book Encyclopedia, The.*
   a. From egg to polliwog, pp. 2625–2628
   b. Development of plant embryos, Vol. 7, pp. 2789–2790

VISUAL AIDS

FILMS (16 mm.)

A. U. S. Dept. of Agriculture, Washington, D. C.
   1. Time-Lapse Studies of Plant Growth. 1 reel, silent, free.
   2. Ovulation. 2 reels, silent, free.
   3. In the Beginning. 2 reels, sound, free.
B. Eastman Teaching Films Company, Rochester, New York.
   1. Development of a Bird Embryo. 1 reel, silent, $24.00.
C. Indiana University, Extension Division, Bloomington, Indiana.
   1. The Life Cycle of a Frog. 1 reel, silent, $1.00 per day.
D. University of Chicago, Biological Science Service, Chicago, Illinois.

CHARTS

Series	*Titles*
Smalian Embryologic	Fertilization Process
	Segmentation of Frog Egg
	Formation of Internal Organs
	Propagation and Development of Young Mammals

UNIT THIRTEEN

THE LAWS OF HEREDITY AND THE IMPROVEMENT OF MANKIND

SUGGESTIONS TO THE TEACHER

The laws of heredity and their application in the breeding of plants and animals and the improvement of the human race are presented in this unit. Details concerning the mechanism of heredity —its location and how it operates—and the laws derived therefrom are first included. A thorough knowledge of these laws enables the student to understand what plant and animal breeders mean by such terms as *selection, hybrid,* and *mutation.*

Since the subject matter is technical, it is important that each step be made clear as the work progresses. To this end many diagrams are provided. All these should be carefully used to help carry the story.

Finally, some consideration should be given to the relation of the laws of heredity to the solution of social problems. At first thought the application of these laws may seem extremely difficult. As a matter of fact, however, if we fully see the necessity of following certain suggestions given in this unit, and take careful steps to improve the general conditions in the environment, we shall find that a great deal can be accomplished.

OBJECTIVES

I. Facts and principles

A. To learn that like tends to beget like in both plants and animals
B. To become acquainted with the Mendelian Laws of heredity
C. To recognize the difference between pure-bred and hybrid stock
D. To learn how a knowledge of the laws of heredity will help in the improvement of plants and animals

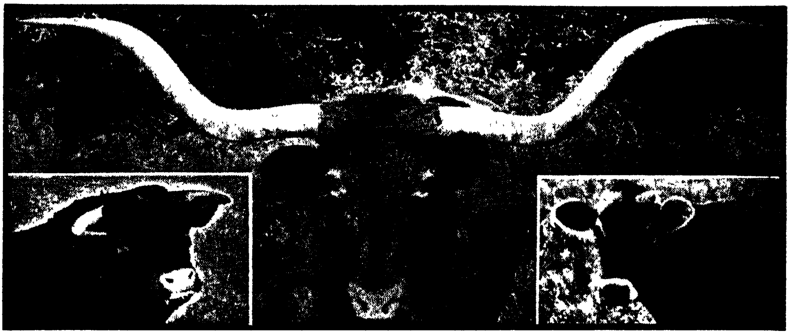
II. Attitudes

A. To build up a more hopeful outlook on life because of the natural process of selection
B. To recognize the fact that all living things may be improved through selective breeding

UNIT THIRTEEN

THE LAWS OF HEREDITY AND THE IMPROVEMENT OF MANKIND

INHERITANCE LAWS IN OPERATION



Breeders often distinguish domestic and wild cattle by their horns. The head in the center is that of the famous longhorn, noted for its very long horns. Breeders are now allowing this type of cattle to disappear. They much prefer the shorthorn like that in the picture at the left or the hornless in the picture at the right. You will learn later in the unit how the first hornless calf came to be.

ALEXIS—A BLEEDER

PREVIEW

Nicholas II was the last czar of the Russian Empire. His son, Alexis, the little czarevitch, was in constant danger of losing his life because of an abnormal tendency to bleed profusely even from the slightest cut. People who possess this peculiar characteristic are known as bleeders. They must be particularly careful to avoid injury, as it may result in a fatal hemorrhage. The bleeding characteristic recurs frequently in certain families, although, of course, only certain members of a family are affected. It was especially common among the earlier royal families of Europe, often resulting in death. Fortunately, today cases of the disease are very rare.

A FORMER ILL-FATED IMPERIAL FAMILY

Brown Brothers

This is the last portrait of the Russian Imperial family. The "little czarevitch" is seated in front of his mother, who transmitted haemophilia, or bleeding disease, to her son.

Why does this condition exist in the bodies of certain people, since in case of injury blood normally clots, thus preventing excessive bleeding? Why has it occurred so often among the royal families of Europe? Why did it affect the little czarevitch, but not his sisters? The answers to these questions may be drawn from the story of heredity.

PROBLEMS

1. **How do we know that certain laws of heredity are in operation?**
2. **What are the laws of heredity?**
3. **How do variations occur among plants and animals?**
4. **How can we improve plants and animals by applying the laws of heredity?**
5. **How can we improve our own kind?**

Problem 1. How do we know that certain laws of heredity are in operation?

The basic principle in reproduction is cell division. When a single-celled animal, such as an amoeba, reproduces, it does so by the division of its one original cell into two daughter cells. Thus two amoebae are formed. Even when sexual

reproduction takes place in a many-celled animal, such as a mammal, the process is still, basically, cell division. The union of an egg and a sperm results in a new one-celled embryo which then grows by cell division into a new individual.

Each organism reproduces its kind. Since cells are very small, we are likely to think of them as being alike in form and structure. Then, since cell division is the fundamental factor in reproduction, we are likely to think of all daughter cells as being exactly alike. We know, however, that the protoplasm must vary or there would not be the countless species of plants and animals that inhabit the earth. Thus we find dogs, cats, elephants, snakes, eagles, wrens, cactus plants, apple trees, and myriad other forms of life. When dogs reproduce, they bear puppies, not snakes; when cats reproduce, they bear kittens. Pine trees produce pine trees and apple trees produce apple trees. The fact that each plant and animal reproduces its own kind shows that certain characters are transmitted from parent to offspring. The transmission of certain characters from parent to offspring is known as *heredity*.

MANY VARIATIONS AMONG ORGANISMS OF ONE KIND

From the foregoing we might think that, since each animal or plant reproduces its own kind, all individuals of that kind would be exactly alike. For example, we might think that all dogs should be alike, all cats, and all apple trees. We know from experience, however, that this is not true. As a matter of fact, no two living things are exactly alike, even two brothers, two sisters, two pigeons, or two peas.

Certain variations caused by environment. Certain variations may be traced directly to the effects of environment. One environmental factor, food, has an especially powerful effect upon plants and animals. The queen of a colony of bees must have a special food known as royal jelly. The workers of the colony, although females, never develop reproductive powers because they get none of this jelly. It has been found that if canary birds eat red pepper at the time of

molting, they will take on an orange color instead of the usual pale yellow. In the Alps, people often suffer from *cretinism* (krē′tĭn-ĭz'm), a disease caused by a lack of iodine in food and drink. Plants likewise show the powerful effect of food. In a rich, loamy soil, for instance, they are usually strong and vigorous, but in a poor clay soil they are stunted and spindling.

Other environmental factors also wield a strong influence upon living organisms. This is well illustrated by the bent and stunted trees on high mountains, where the wind is strong and changes of temperature are extreme. Authorities in the

VARIATIONS DUE TO ENVIRONMENT

Three poor and four good sugar beets. The beets on the left were grown in hard clay soil. Those on the right were grown in a sandy loam.

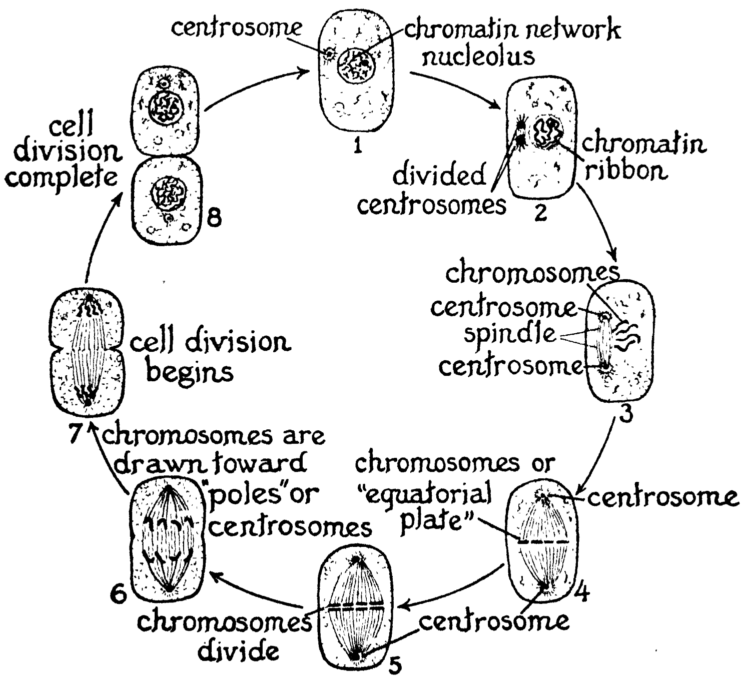
field of sociology have long pointed out that bad living conditions, such as are found in city slums, have a highly detrimental effect upon health and character.

Other variations caused by the operation of inheritance factors. Variation, however, cannot be completely explained by environment. Two dogs may be given the same kind and quantity of food and kept under identical conditions and yet not be alike. Two children of the same parents, reared under the same conditions, are always somewhat different. These facts indicate that characters, such as shape, size, texture, height, width, weight, color, tissues, organs, dispositions, and peculiarities, cannot be explained by the effect of environment alone, but must be explained in part by heredity.

Problem 2. What are the laws of heredity?

The characters which parents transmit to their offspring are carried by small bodies in the nucleus of cells known as *chromosomes*. When parent cells divide, the chromosomes also divide at the same time. One half of each chromosome goes to each of the two daughter cells. Thus each daughter cell has the same number of chromosomes as the original cell, and hence the same characters as the original cells. The following illustration shows how the chromosomes behave in the process of cell division.

THE VARIOUS STAGES IN THE DIVISION OF AN ANIMAL CELL

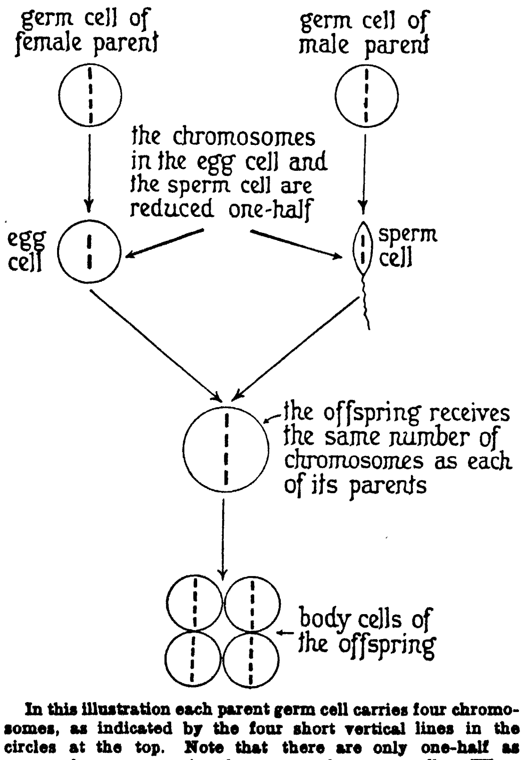


Notice that the centrosome divides and forms two poles from which the spindle fibers develop. The chromosomes form an equatorial plate, then split and move toward the poles. When the chromosomes reach the poles, the division is complete, and each daughter cell has the same number of chromosomes as the parent.

TRANSMISSION OF HEREDITARY CHARACTERS IN SEXUAL REPRODUCTION

Body cells and germ cells. Before we can understand the operation of heredity in sexual reproduction, we must learn the difference between *body cells* and *germ cells,* which are found in all organisms that reproduce sexually. Body cells are those which divide by mitosis and make up the main structure of the body of an organism. Germ cells are those that give rise to eggs and sperms, or the reproductive cells by which higher forms of life reproduce their kind. Each body cell of an organism always carries the same number of chromosomes as each germ cell. Thus each body cell of a horse carries sixty chromosomes, and each germ cell a like number. We shall now learn how these cells function in the transmission of characters from one generation to another.

REDUCTION IN CHROMOSOMES



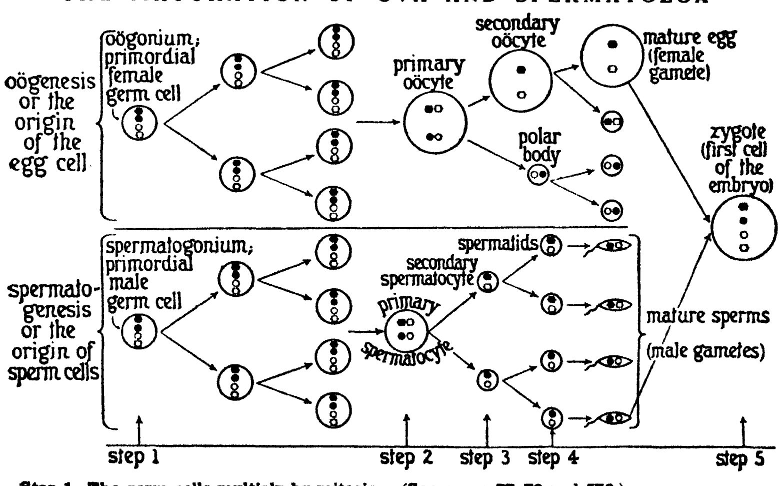
In this illustration each parent germ cell carries four chromosomes, as indicated by the four short vertical lines in the circles at the top. Note that there are only one-half as many chromosomes in the egg and sperm cells. When these cells unite, however, the offspring contains the same number of chromosomes as each of the parent cells.

Chromosomes reduced in number in reproductive cells. When a sperm cell and an egg cell unite, the resulting one-celled

embryo divides into two cells, these two into four cells, these four into eight cells, and so on until the body of the organism is fully developed. Suppose this new organism, like the horse, carries sixty chromosomes in its body cells. This means that its male parent also carried sixty chromosomes in his body cells and that its female parent carried sixty chromosomes. Naturally, then, we wonder why the new organism does not carry one hundred twenty chromosomes in its body cells. The explanation is that the *egg* and *sperm* cells always carry just half as many chromosomes as the body cells. Thus if the new organism contains sixty chromosomes in its body cells, the sperm cell of the male parent carried thirty chromosomes and the egg cell of its mother also carried thirty chromosomes. The union gave the new organism the same number of chromosomes as each of its parents had.

How the reduction takes place. The process by which germ cells divide to form eggs and sperms differs from ordinary

THE MATURATION OF OVA AND SPERMATOZOA



Step 1. The germ cells multiply by mitosis. (See pages 77–79 and 576.)
Step 2. The chromosomes pair.
Step 3. The chromosomes are reduced in number.
Step 4. Eggs and sperms are produced, each having one-half the number of chromosomes in a regular germ cell. Maturation begins with step 3 and ends with step 4.
Step 5. The zygote, a one-celled embryo, is formed. It has the same number of chromosomes as the original germ cells.

mitosis, as we may see by looking at the illustrations on pages 629 and 631. In other words, the chromosomes of the germ cells do not split in halves, but line up in pairs. Then, when the cells divide, each new cell takes on just half the number of chromosomes as there are in the parent cell. The process by which germ cells thus divide to form eggs or sperms is called *maturation* or *ripening*, during which the chromosomes are reduced in number.

Number of chromosomes in various organisms. Chromosomes are the most important parts of cells concerned with the transmission of hereditary characters. The number of chromosomes is always the same in both the body cells and the reproductive cells of plants and animals of the same species. That is, there are just as many chromosomes in the cells of one plant or animal of a certain species as there are in the cells of another plant or animal of the same species. The following table shows the number of chromosomes in the cells of various forms of life.

THE NUMBER OF CHROMOSOMES IN CERTAIN PLANTS

Name of Organism	In Body Cells	In Mature Egg or Sperm
Spirogyra	24	12
Moss	40	20
Bracken fern	64	32
Wheat	20	10
Corn	20	10
Onion	16	8
Pine	24	12
Pea	14	7

THE NUMBER OF CHROMOSOMES IN CERTAIN ANIMALS

Name of Organism	In Body Cells	In Mature Egg or Sperm
Housefly	12	6
Trout	24	12
Frog	26	13
Chicken	18	9
Rat	16	8
Horse	60	30
Cattle	16	8
Man	48	24

THE STORY OF THE GENES

According to the preceding table man has forty-eight chromosomes in his body cells. When we consider his characters, such as weight, height, and color of eyes, we realize that he has many more characters than he has chromosomes. The same is true in the case of every organism. In view of this fact, we naturally wonder how so many characters can be developed. The answer is: by tiny bits of matter known as

genes (jēnz), or determiners. Each chromosome is made up of a number of genes that function as determiners of characters.

The law of independent unit characters. Each character, such as the color of hair, is called a *unit character* because it is transmitted independently of other characters. There are two genes in the body cells for each unit character, one being in one chromosome and one in another chromosome. In the egg and sperm cells, however, there is but one gene for each unit character. When an egg and a sperm unite, the gene for a unit character in the one associates with the gene for the corresponding unit character in the other to provide the two genes for the unit character in the body cells of the new organism.

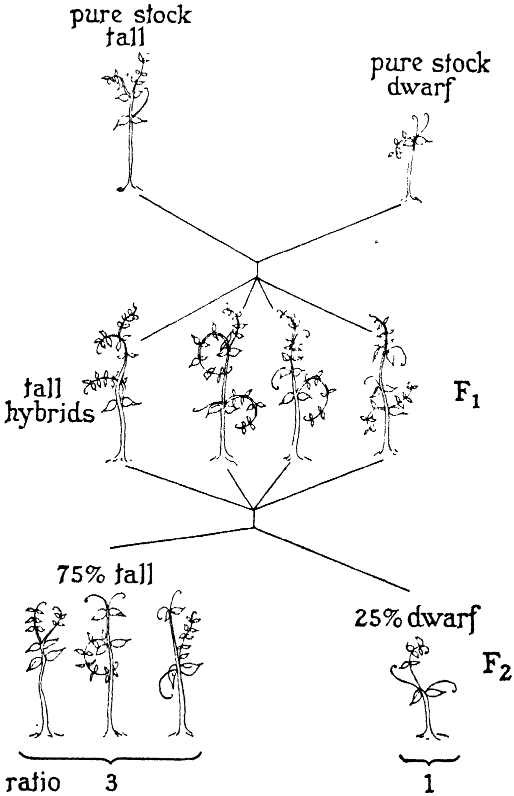
The fact that unit characters are transmitted independently is known as the *law of independent unit characters.* This law was discovered by a famous Austrian monk, Gregor Johann Mendel (1822–1884), who was one of the first to experiment in the field of heredity. He is the forerunner of the many scientists who have provided the information that we have today.

The law of dominance. Mendel traced the inheritance of the unit character of height by taking *tall peas* of *pure stock* (those that had produced only tall peas) and cross-pollinating them with *pure-stock dwarf peas.* We should naturally expect the resulting peas to show a blending of the two characters, being neither tall nor dwarf but of medium height. The experiment showed, however, that all the offspring from the crossing were tall. Hoping to solve the problem, Mendel continued his investigations by crossing plants of the first generation (sometimes called F_1, or first filial generation). As a result he found that the plants in the second generation (sometimes called F_2, or second filial generation) were not all tall. Instead, 75 per cent of them were tall and 25 per cent were dwarf. In other words, they split in a three-to-one ratio.

Although the peas belonging to the F_1 generation were all tall plants, they evidently were not pure stock, since some of their descendants were dwarf rather than tall. Plants of mixed origin, as the peas of the F_1 generation, are commonly known as *hybrids* or *hybrid stock.* The dwarf character

evidently was present in the peas of the F_1 generation, but remained hidden. Characters of this sort that do not appear in the hybrid but may be transmitted are called *recessive*. Characters, as tallness of peas, which appear in hybrid stock are called *dominant*. The relation of dominant and recessive characters is commonly known as the *law of dominance*.

MENDEL'S EXPERIMENT WITH TALL AND DWARF PEAS, SHOWING THE 3:1 RATIO



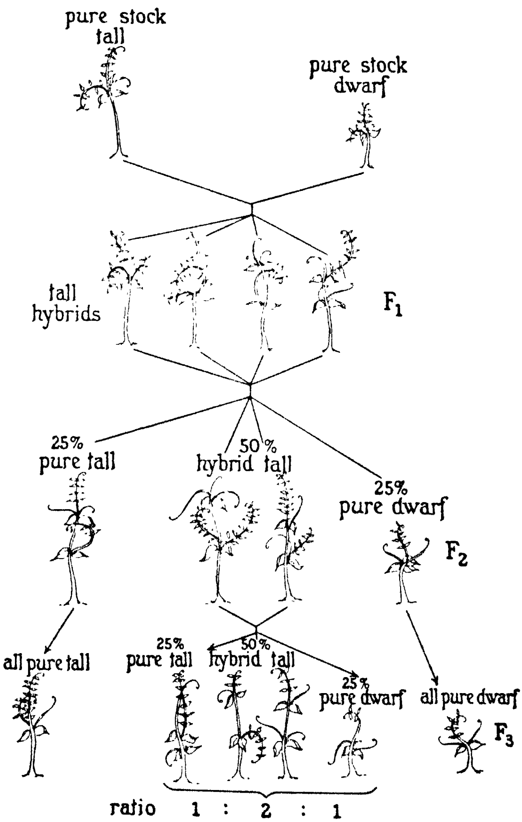
The plants of the F_1 generation illustrate Mendel's law of dominance. Note that all four of the plants are tall.

The law of segregation. When Mendel carried his experiment to the F_2 generation, as already stated, he found both tall and dwarf peas that resembled the original ancestral stock. The illustration at the left shows the number of each that he found. In this manner he arrived at the *law of segregation* or the separation of unit characters in the germ cells of hybrid individuals. The genes for the unit characters of height were separated in the F_1 generation hybrids at the time of the formation, or segregation, of the gametes (sperm and egg). This discovery is important, for it explains how certain characters may be entirely hidden in

a hybrid generation and appear later in the offspring. When hybrid stock is mated with hybrid stock of the same kind, the offspring will reveal the characteristics of the ancestors.

By further experimentation Mendel found that the 25 per cent of dwarfs of the F_2 generation were pure stock; that is, they continued to produce dwarfs in all future generations if they were kept to themselves and were not cross-pollinated. Of the 75 per cent of tall plants, however, he found that one-third were pure tall plants and the remainder were hybrids. The hybrids of the F_2 generation reproduced the same as the hybrids of the F_1 generation. In short, they broke up into a three-to-one ratio, which means that three plants had a dominant character and one a recessive character. If we follow the record still further, as we may by noting the number of pure talls and dwarfs in the F_3 generation illustrated above, we shall find that the ratio is really 1:2:1.

MENDEL'S EXPERIMENT WITH TALL AND DWARF PEAS, SHOWING THE 1:2:1 RATIO



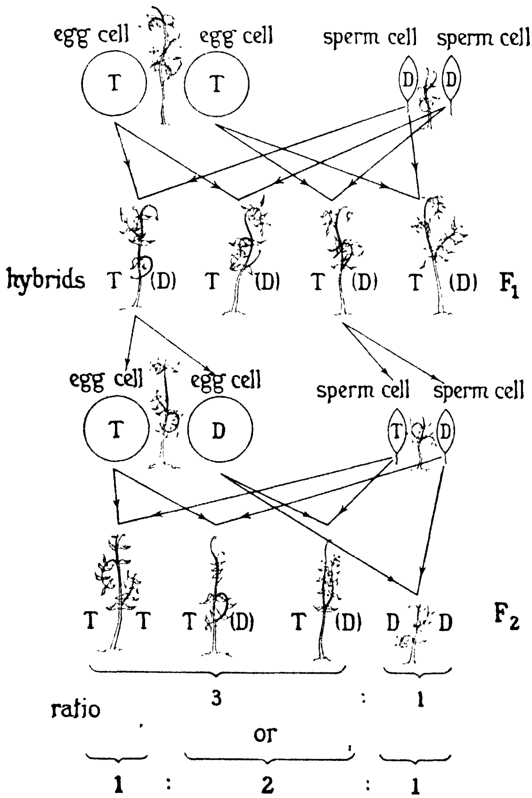
The plants of the F_2 generation segregate (sort out) into types resembling the original stock from which they came.

Explaining Mendel's Laws by Means of Genes

As we have already learned, body cells and germ cells contain two genes for each unit character, but sperm and eggs cells contain only one gene for each unit character. In other words, a reduction follows. In view of this fact, let us consider exactly how genes function in determining the unit characters.

How the genes associate. In the body cells and germ cells of tall pea plants (pure stock) there are two genes for the unit character of height. Suppose we represent these two genes by TT. In like manner, in the germ and body cells of the dwarf plants (pure stock) there are two genes for the unit character of dwarfness. Let us represent these two genes by D.D. The sperm and egg cells of the tall specimens contain one gene represented by T, and those of the dwarf specimens one gene represented by D. Suppose an egg of a tall plant is fertilized by a sperm of a dwarf plant. The diagram above shows how Mendel's Laws operate in the F_1 and F_2 generations.

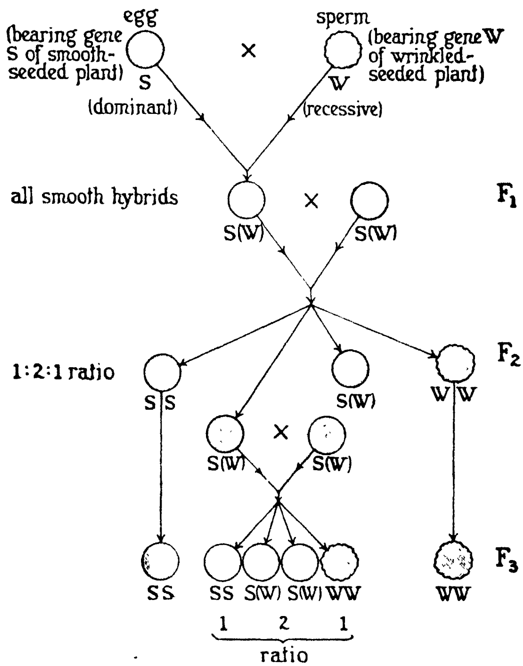
WORK OF GENES IN THE CROSSING OF TALL AND DWARF PEAS



This illustration fully explains Mendel's laws of dominance, segregation, and independent unit characters.

In the F_1 generation, following the fertilization of the egg of a tall plant by the sperm of a dwarf plant, a T gene always associates with a D gene, or they are cross-mated. In the F_2 generation, however, two T genes associate in one plant and two D genes in another. The association of these genes determines the hybrid stock. If two dominant genes associate, as TT, the offspring will be pure stock. Likewise if two recessive genes associate, as DD, the offspring will be pure stock. If one dominant gene associates with one recessive gene, as TD, the offspring will be hybrid but will have the character of the dominant type.

DOMINANCE IN THE CROSSING OF SMOOTH AND WRINKLED PEAS



When smooth pea plants (pure stock) are crossed with wrinkled plants (pure stock), smoothness is dominant.

The diagram at the right applies the work of the genes to smooth and wrinkled peas. The character of smoothness is dominant, that of wrinkledness recessive. The diagram shows when hybrids and pure stock plants appear.

Making helpful applications. It will be helpful at this time to choose some of the characters from the table on the following page and make diagrams to show how dominant and recessive characters appear in the F_1, the F_2, and the F_3 generations. The various diagrams will serve as guides.

A Few Dominant and Recessive Characters

Organism	Dominant Character	Recessive Character
Man	Dark skin	Light skin
	Brown or black eyes	Blue eyes
	Curly hair	Straight hair
	Normal mind	Feeble-mindedness
Dogs	Light hair	Black hair
Cattle	Hornlessness	Horns
Barley	Beardless heads	Bearded heads
Wheat	Late ripening	Early ripening
Corn	Yellow	White
	Round grain	Wrinkled grain

Incomplete Dominance of Characters

Sometimes in the operation of Mendel's Laws there is an incomplete dominance of characters. There is a blending of characters rather than an appearance of one or the other.

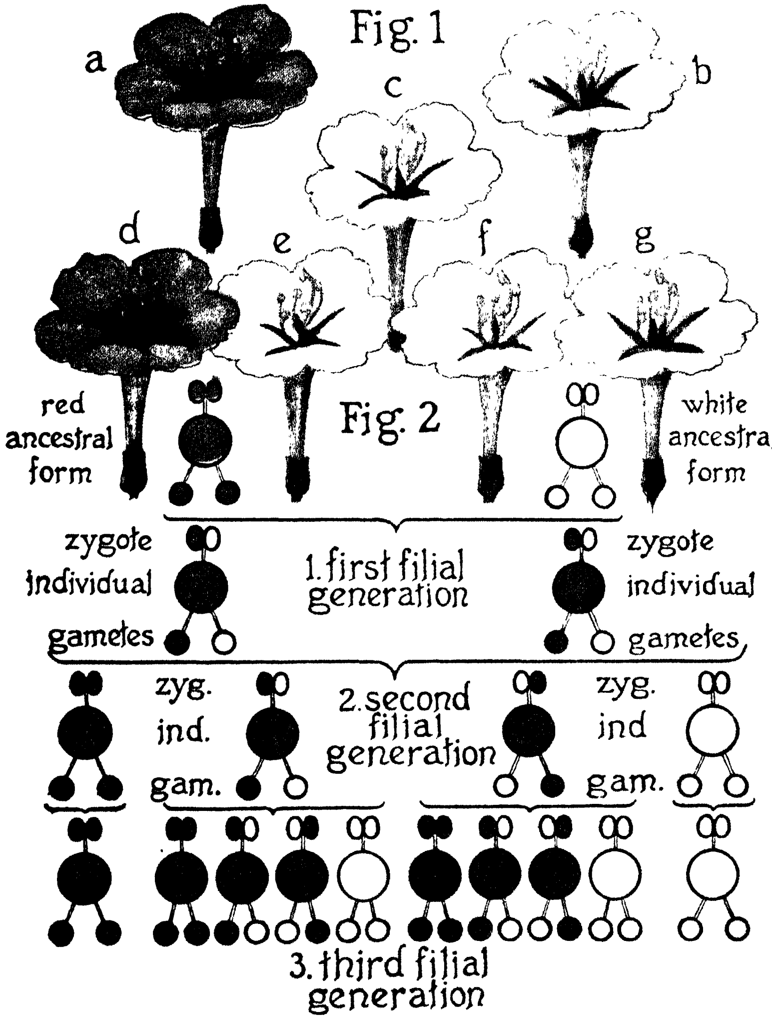
Two striking examples of incomplete dominance. If pure-stock white four o'clock flowers are crossed with pure-stock red flowers, all members of the first generation will be pink hybrids. Since there is a blending of red and white, the lack of dominance is evident. In the F_2 generation, however, the typical Mendelian ratios from the pink hybrid occur: one pure white, two pink hybrids, and one pure red, as shown in the illustration on the following page.

If pure-black Andalusian fowls are mated with pure-white fowls, all fowls of the F_1 generation will be speckled black and white, or so-called "blue." These blues, when mated, produce offspring in the ratio of one pure black, two blue hybrids, and one pure-white fowl. To produce only blue Andalusian fowls, blacks must always be bred with whites.

The Transmission of More Than One Unit Character

Our discussion has been confined largely to the transmission of a single unit character. However, reproductive cells transmit many unit characters at once. Indeed, the combinations of characters are so numerous that it is not practical to attempt to show them by diagrams. Some idea of the complexity of the process, however, may be obtained by following through the transmission of two unit characters together.

INCOMPLETE DOMINANCE AS ILLUSTRATED BY THE PINK FOUR-O'CLOCK



Haeckler Biology and Heredity Chart —Courtesy A. J. Nystrom & Company

In order to produce all "pinks," the parental stocks must be pure-stock red (RR) and pure-stock white (WW). The F_2 generation shows the operation of what Mendelian law?

The transmission of the color and length of hair in guinea pigs. For a study of the transmission of two characters at once, let us consider the color of hair of the guinea pig as one character and the length of hair as another. Suppose we consider what happens when a black, short-haired guinea pig is crossed with a white, long-haired guinea pig. For purposes of illustration we may represent the genes for the color of hair by B and W respectively and those for the length of hair by S and L respectively. It happens that in this particular case black hair is dominant over white hair and short hair over long hair. Hence all of the offspring of the F_1 generation have black, short hair. Since we are considering the transmission of two unit characters, the offspring of this generation are called *dihybrids* instead of *hybrids*.

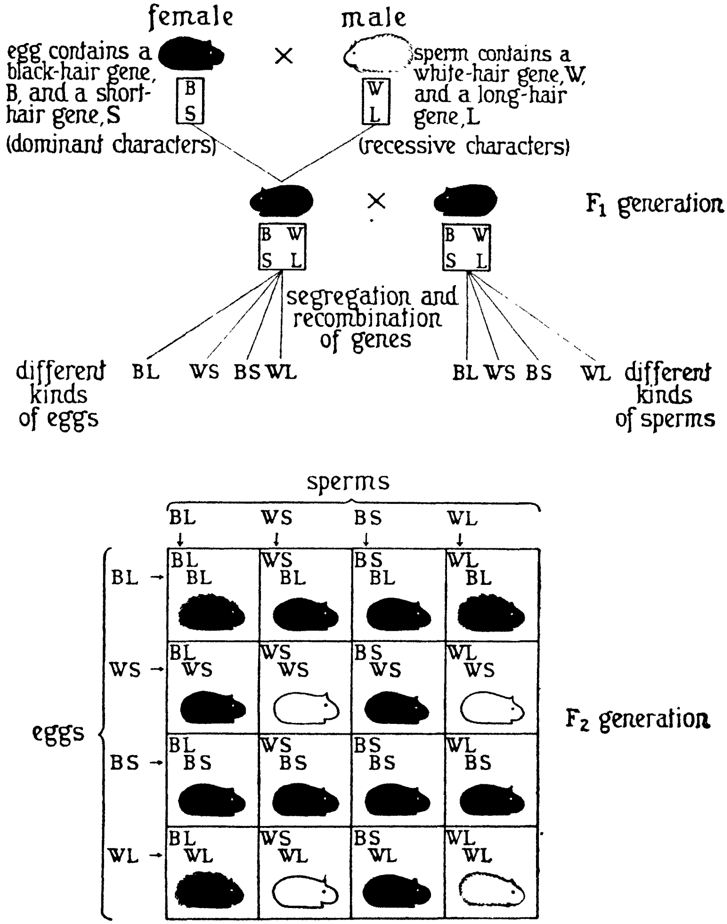
As the dihybrids are crossed, complexity arises in the combination of genes. The upper part of illustration on the following page shows how the genes or unit characters separate and recombine during the formation of eggs and sperms. Here we find four different combinations of genes in eggs and sperms: black, short hair (BS); white, long hair (WL); and two new combinations, black, long hair (BL) and white, short hair (WS).

If all these genes in the egg and sperm cells should now combine in all their possible combinations to transmit characters to the F_2 generation, the results would be as shown in the lower part of the illustration on the following page. In short, there would appear in the F_2 generation nine black guinea pigs with short hair; three black guinea pigs with long hair; three white guinea pigs with short hair; and one white guinea pig with long hair. Of these sixteen individuals, twelve would be dihybrids, and four, pure stock.

Summary of the Laws of Heredity

In experiments with peas Mendel discovered (1) that unit characters are transmitted independently; (2) that certain unit characters are dominant over others in hybrids; and (3) that there is a segregation of unit characters at the time of the formation of gametes (eggs and sperms).

DIHYBRID RATIO AS ILLUSTRATED BY GUINEA PIGS



If a guinea pig carrying two dominant characters — black hair and short hair — is crossed with a guinea pig carrying two recessive characters — white hair and long hair — the resulting hybrids of the F_1 generation will have only black and short hair. When these hybrids are crossed, a segregation and recombination of the genes take place, resulting in four different gene combinations in eggs and sperms. The union of these eggs and sperms in all their possible combinations results in sixteen different individuals as shown in the squares. You will see, however, that there appear to be only fourteen different kinds of guinea pigs. Of the sixteen guinea pigs, only four are pure stock: one with black, long hair (BL, BL), one with white, short hair (WS, WS), one with black, short hair (BS, BS), and one with white, long hair (WL, WL).

Findings since the time of Mendel. Investigation since the time of Mendel has disclosed that unit characters are determined by genes. There is one gene for each unit character in sperm and egg cells. When an egg is fertilized by a sperm, the gene for a certain unit character in the egg, such as tallness, associates with the gene for the same unit character in the sperm. When both the genes are either dominant or recessive, the offspring will be pure stock. When one of the genes is dominant and the other recessive, all offspring of the first (F_1) generation will be hybrids and will have the character of the dominant type. The descendants of these hybrids, the members of the second (F_2) generation, will appear in the ratio of three dominants to one pure recessive. Among the three dominants, one will be a pure dominant and two will be hybrid dominants.

Sometimes exceptions occur to the law of dominance, as when pink flowers result from the cross-mating of pure-stock white four o'clocks and pure-stock red ones. Even here, however, the law of segregation operates as usual, and the offspring of the pink hybrids occur in the regular Mendelian ratio of 1:2:1.

Problem 3. How do variations occur among plants and animals?

In the early part of this unit we learned that certain variations in plants and animals may be traced to the effects of food and environment and that other variations may be traced to heredity. The story of genes helps us to understand how variations occur in heredity.

Characters, as we have learned, are transmitted through the reproductive cells from one generation to another. Parent organisms inherit certain genes from their ancestors and pass them on to their offspring. The chance combinations of the genes in the sperm and the egg determine the characters, or traits as they are sometimes called, of the offspring. A child may have red hair, blue eyes, a light skin, a tall body, and a cheerful disposition, but its parents may lack

all of these characters. Thus he is a hybrid in these characters because of certain combinations of ancestral genes. The same situation exists as in the case of the hybrid pink four-o'clocks described on page 638, in which none of the plants of the F_1 generation are exactly like either parent.

MUTATION

The foregoing shows that many variations in plants and animals are brought about by heredity. Thus a flower garden may contain roses, lilies, and pansies that vary widely in size, color, and form. Such varied characters usually do not breed true, but split up to resemble their ancestral types.

An abrupt departure from type. Occasionally an abrupt departure from type occurs, known as *mutation,* the variations themselves being known as mutations. The theory of mutation was first announced in 1904 by a Dutch botanist named Hugo de Vries (dē vrēz'). He formulated the theory as a result of work with ordinary garden primroses. The theory of mutation explains the appearance of a black sheep in a flock of white sheep, a red ear of corn among white and yellow ears, or a red sunflower among ordinary yellow sunflowers.

Apparently the mutations are due to certain variations in the egg or sperm of the parent stock. In the case of the first hornless calf, hornlessness was a dominant character which was transmitted directly to descendants, thus originating hornless cattle. In the case of the black sheep, blackness is recessive, and not transmitted directly. When an individual departs abruptly from parental types and transmits its characteristics directly to future generations, it is known as a *mutant* or *sport.*

The cause of mutation. According to the best evidence, as already indicated, mutation is caused, at least in part, by certain changes in the protoplasm of the germ cells, which give rise to the sperm or egg cells.

1. *Genes may interchange positions.* In the pairing of the chromosomes as the sperm or egg cells are being formed, the genes sometimes interchange their positions.

2. *Chromosomes may become changed in character.* In pairing, the chromosomes themselves occasionally become twisted together, and a part of one chromosome probably unites with a part of another chromosome.
3. *The chromosomes may become changed in number.* It has been found that certain mutants differ from the original parental stock in the number of chromosomes.
4. *Genes may be affected by X-rays.* Although scientists generally believe that genes are not affected by environment, experiments with the fruit fly, Drosophila, have shown that gene mutations sometimes occur when the germ cells are exposed to X-rays.

Problem 4. How can we improve plants and animals by applying the laws of heredity?

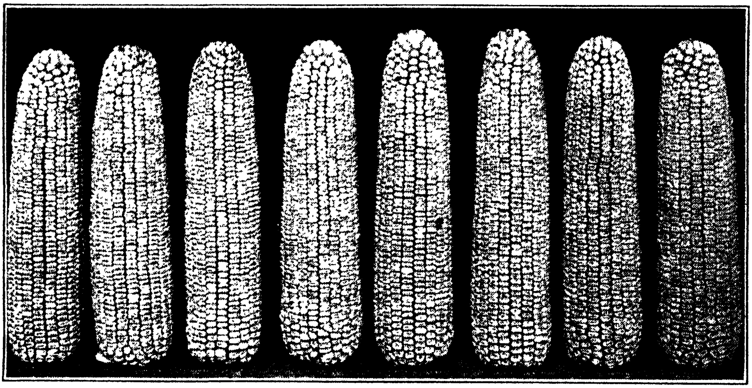
Breeders of plants and animals are greatly indebted to Gregor Mendel and other scientists who have studied and explained the operation of the laws of heredity. Through the application of these laws remarkable improvement has been made in many life forms. We shall next study some of the applications that have been made.

WAYS OF APPLYING MENDEL'S LAWS

The value of selection. It is only within comparatively recent years that the real value of selection in breeding has been understood. August Weismann (1834–1914) was one of the first to give us reliable information on the subject. He experimented with rats, cutting off their tails for many generations to see whether a short-tailed variety could be produced. He found, however, that the sperm and egg cells were not affected by such a process and that the rats continued to reproduce rats with equally long tails. However, by selecting rats that possessed the shortest tails and mating them together, he finally obtained a short-tailed variety.

Farmers apply the *principle of selection* when they use seed from the best ears of corn and choose for breeding purposes the cows that give the greatest quantities of rich milk.

THE SELECTION OF GOOD SEED CORN IMPORTANT



Note the uniform, well-filled rows, the length and circumference of the ears. Such desirable characteristics are likely to appear in corn produced from this type of seed corn.

The value of hybridizing. It has been found that certain hybrids are decidedly superior to their parents in certain characters. Varieties of chickens, for instance, have been obtained that lay three times as many eggs as their ancestors. The better varieties of grapes have been developed by *hybridization,* that is, cross-breeding. Only closely related species and varieties, however, may be cross-bred or hybridized. Thus red and yellow corn may be cross-pollinated, but not red corn and an onion.

The value of mutants. A breeder of plants and animals is constantly on the lookout for a desirable mutant. A farmer of New England, for example, is responsible for the breed of Ancon sheep. He discovered in his flock a short-legged sheep that could not jump fences as well as a long-legged sheep. Seeing the practical advantage of a short-legged species, he used the mutant for obtaining the Ancon sheep. The seedless orange has also come about by mutation.

Improved animals likely to revert to original stock. Unfortunately selective breeding does not fully solve a breeder's problems. A mutant crossed with one of the parent stock from which it has mutated will suddenly produce descendants of the original parental type. A few cattle with horns, for

instance, will appear in a herd of hornless cattle. Domesticated animals tend to revert in some of their characters to those of their wild ancestors if permitted to run loose.

PLANTS THAT HAVE BEEN PRODUCED OR IMPROVED BY THE APPLICATION OF THE LAWS OF HEREDITY

Great variety of improvements. The laws of heredity can be applied much more readily among plants than among animals. Many new plants have been secured through the planting of seeds from mutants. Numerous old ones have been improved through the planting of seeds from only the best individuals, such as the largest and best ears of corn or heads of wheat. In addition, many plants that do not ordinarily breed true from seed, as apples, potatoes, lettuce, and grapes, have been improved by vegetative propagation. In other words, buds and pieces of roots or stems have been used to grow new individuals. Such buds and pieces have been taken from the best individuals, as in the case of propagating from seeds.

VEGETABLES UNKNOWN TO YOUR GREAT-GRANDMOTHER

Ewing Galloway

Simpson lettuce and Idaho potatoes are the result of the improvement of plants by breeders.

As a result of the foregoing work, we now have numerous varie-

SPINELESS CACTUS DEVELOPED BY BURBANK

Brown Brothers

This picture shows prickly pear or spineless cactus and its fruit. The fruit is edible. The spineless cactus slabs are used as green fodder for cattle.

ties of grapes, peaches, cherries, apples, and plums in our orchards; many varieties of corn, wheat, rye, rice, and cotton in our fields; many color patterns of sweet peas, roses, morning glories, and tulips in our gardens; and countless other variations of domesticated life.

The peer of plant breeders. The most widely known of all the persons who have worked for the improvement of plants is Luther Burbank (1849–1926). He first attracted attention in 1872 when he developed the Burbank potato. Potatoes multiply, as we know, by vegetative propagation and do not ordinarily produce seed. One day, however, Burbank discovered a berry growing on one of his potato vines. He took the few ripened seeds from the berry, planted them, and thus produced the potato that bears his name.

From 1875 on Burbank gave his entire time to a study of the selection and breeding of plants. Among his creations are the thornless cactus, a new variety of tomato, heavier-yielding corn and wheat, the delicious plumcot, and the Shasta daisy.

HOW THE LAWS OF INHERITANCE FUNCTION IN ANIMAL BREEDING

Courtesy U. S. Department of Agriculture

A pure-bred ram was mated with the poorly fleeced ewe shown at the right. Notice how much better fleeced the offspring is than the mother.

ANIMALS THAT HAVE BEEN PRODUCED OR IMPROVED BY THE APPLICATION OF THE LAWS OF HEREDITY

Improvements broad and varied. Animals cannot be multiplied vegetatively. The breeder of animals must depend, therefore, upon hybrids, which, of course, do not breed true; upon careful selection to insure desired unit characters; and upon the occurrence of mutants for the production of new and better varieties. In spite of these limitations, many varieties of animals have been improved or produced. Speedy race horses, for example, have been secured by the mating of running horses. Heavily built work horses have been secured by the mating of heavily built horses. Likewise, numerous breeds of chickens, ducks, cats, geese, hogs, and cattle have come about through the operation of laws of heredity.

Problem 5. How can we improve our own kind?

The story of the improvement of life forms would not be complete without consideration of the improvement of the

human species as well. In this connection we are primarily concerned with feeble-mindedness and its relation to crime and disease. It is estimated that there are about three hundred thousand mental defectives in the United States. Many of them, of course, are housed in institutions for the feeble-minded, asylums, and houses of correction of various kinds. Unfortunately, others are not confined and make up a large precentage of our paupers, drunkards, vagabonds, and physical degenerates. That the problem is a serious one is apparent from the fact that each year we spend $100,000,000 to care for the feeble-minded and many more millions to combat crime.

THE OPERATION OF MENDEL'S LAWS IN MAN

A number of studies have been made to show the relation between heredity and feeble-mindedness, criminality, pauperism, and physical degeneracy. The results of one of these studies follow. We should keep in mind, however, that environment is also a factor to be considered.

The Transmission of Undesirable Social Characters or Traits

Margaret, the mother of criminals. One of the most striking records of the inheritance of tendencies to crime is shown by the family of Jukes (a fictitious name). Max Jukes was a shiftless vagabond who lived in the early part of the eighteenth century. One of his sons married a girl by the name of Margaret who came from a family noted for its degeneracy. This marriage resulted in such a long line of descendants with criminal records that Margaret became known as "the mother of criminals." A study of the family in 1877 revealed the following startling record:

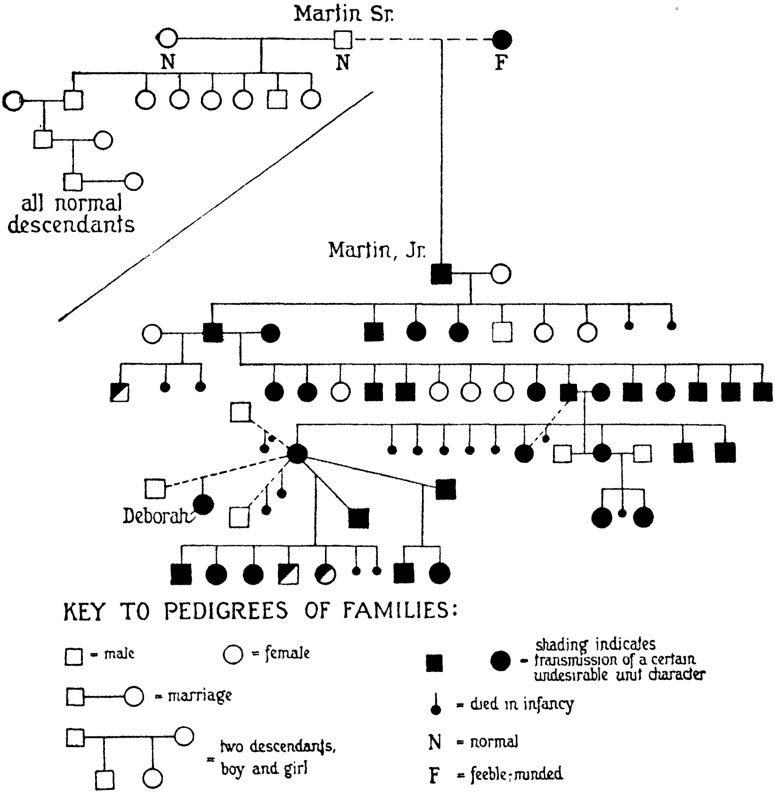
300 had died in infancy
310 had been paupers
440 had been physical degenerates
130 had been professional criminals
Only 20 had learned a trade, and 10 of these had learned their trades while in prison

A family study showing both good and bad inheritance — the Kallikaks. The story of the Kallikak (a fictitious name) family is enlightening because it shows the results of two strains of inheritance. The study began as an attempt to explain the feeble-mindedness of Deborah Kallikak, who at the age of twenty-two had a mental age of nine years, showed no power of concentration, could not add or subtract, and had a childlike, wandering mind. No external defects were noticeable. She was attractive, neat, cheerful, fond of pretty clothes, and showed some skill in music. Her ancestry was traced back to Martin Kallikak, a man of normal character and a soldier of the American Revolutionary War. It was found that he had become the father of a feeble-minded son, the offspring of a feeble-minded mother. It was with this son that the defective line of Kallikaks began. Later, Martin married a normal girl, and from this marriage only normal citizens descended. The contrast of the two families is shown below:

From the Feeble-minded Mother	*From the Normal Mother*
480 Descendants	*496 Descendants*
3 criminals	No criminals
143 feeble-minded	All normal
24 alcoholic	2 alcoholic
33 physical degenerates	No physical degenerates
83 died in infancy	15 died in infancy

A number of the descendants in these two families could not be located, but a sufficient number were tabulated to show a difference in the strains. The illustration on the following page shows the pedigree of the feeble-minded strain. As we study it, we may wonder why the exact Mendelian ratio (1 : 2 : 1) does not follow through. The answer is that this happens only when the original parents are pure stock. If pure-stock normal (NN) married pure-stock feeble-minded (FF), the ratio of Mendel's law of segregation would hold true. Then, too, fortunately feeble-mindedness is recessive in the human race. In the plant and animal kingdoms favorable genes can generally be maintained in pure stock by artificial selection.

PEDIGREE OF THE KALLIKAK FAMILY



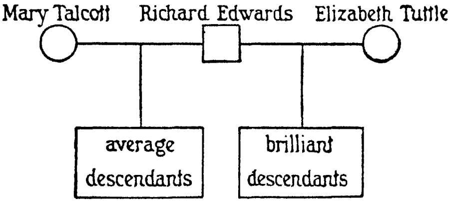
In the human race, however, constant intermarriage continually mixes the genes so that pure stock does not exist.

The Transmission of Desirable Social Characters or Traits

The history of the Edwards family. Now we shall turn to the brighter side of the story of heredity. Instead of considering the transmission of undesirable characters or traits, we shall consider the transmission of desirable ones. Scientists and social workers have provided convincing records on the favorable side just as they have on the unfavorable side.

One of the most interesting stories on the favorable side is the history of the Edwards family. Richard Edwards had two lines of descendants. His first marriage was to Elizabeth Tuttle, a woman of great mental power, and from this union descended one of the most brilliant families ever recorded. His second marriage was to Mary Talcott, a woman of average ability. The second marriage resulted merely in an average line of descendants.

THE TWO BRANCHES OF THE EDWARDS FAMILY



What eugenic lesson can be drawn from the study of the two branches of this family?

A study, in 1900, of the descendants of Jonathan Edwards, a famous theologian and grandson of Richard Edwards and Elizabeth Tuttle, resulted in the following glowing record of achievement and wholesome living. Many of the descendants, as is apparent from the list, were among our national leaders.

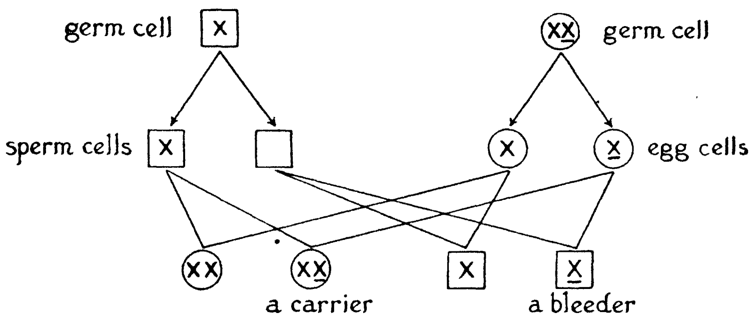
305 college graduates
12 college presidents
100 clergymen
60 prominent physicians
75 officers in the army and navy
60 prominent authors
100 lawyers
30 judges
5 United States senators and congressmen
1 vice-president
80 public officers, such as governors, mayors, and ambassadors
Many others of high standing, such as presidents of banks, railroads, and insurance companies

The Transmission of Physical Weaknesses and Defects

Physical weaknesses rather than diseases inheritable. Our discussion of inheritance in human beings so far has dealt with feeble-mindedness, tendencies to criminality, and

other abnormalities. The question as to whether disease too can be inherited is often debated, but scientists are now generally agreed that it cannot. Certain physical weaknesses that may lead to disease, and certain physical defects, on the other hand, are often inherited. This is true sometimes of a lack of fibrin in the blood. A person so affected may suffer excessive bleeding and is said to have *haemophilia* (hē-mō-fĭl′-ĭ-*ȧ*). Strangely, this defect affects only males, the females being mere carriers that transmit it to their sons. The following illustration shows how the condition develops.

THE TRANSMISSION OF HAEMOPHILIA



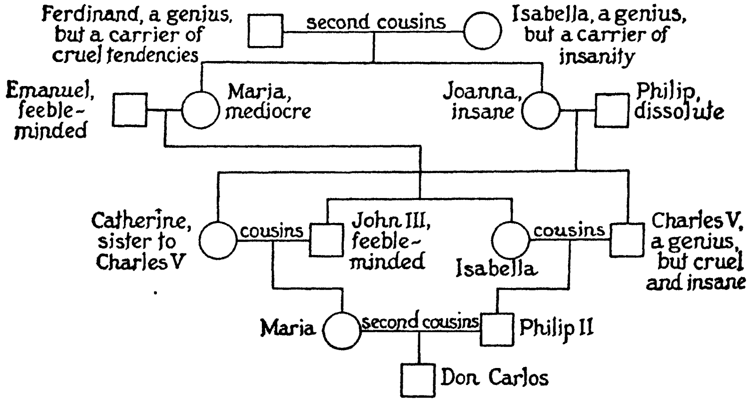
The sex character is related in some way to a chromosome which scientists have termed the X chromosome. Two of these chromosomes are present in the germ and body cells of females, whereas only one is present in males. The underscoring indicates that the gene of haemophilia seems to be linked with an X chromosome. As the defect is dominant in males, the presence of one gene in an individual produces it; as it is recessive in females, two genes must be present before it appears.

THE DANGER OF CLOSE INTERMARRIAGES

Because of the long mixture of genes down through the ages, few if any families possess absolutely pure stock of a favorable type. This means that even the best of families carry a few unfavorable genes which have been derived from ancestors somewhere along the line. Close intermarriages double these unfavorable genes so that they result in unfavorable characters in the descendants. The presence of the same unfavorable genes in both sperm and egg of the parent stock tends to increase greatly the possibility of transmitting the unfavorable characters to the offspring. In many cases,

of course, intermarriages seem to have no undesirable effects, but more often they turn out badly. The dangers involved in intermarriage may be illustrated by the pedigree of Don Carlos, outlined in the following chart.

PEDIGREE OF DON CARLOS



Don Carlos, the son of Philip II of Spain, was one of the most vicious princes in history. He suffered from mental derangement, and his conduct was very disorderly. Fortunately for Spain, he died before there was a chance for him to become king.

THE UPBUILDING OF MANKIND

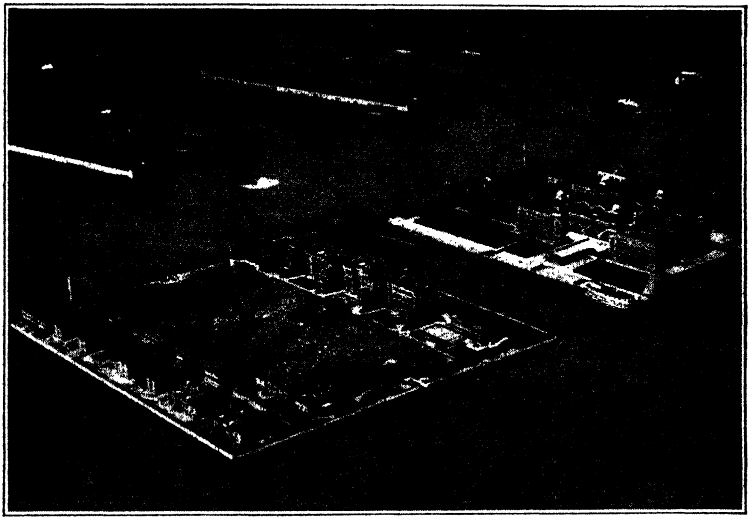
There are two rather distinct ways in which human characters and traits may be improved. One method is by the application of *euthenics* (ū-thĕn′ĭks), or the uplift of society through the improvement of the environment. The other is by the application of *eugenics* (ū-jĕn′ĭks), or the improvement of society by the use of the laws of heredity.

Improvement by environment. Fortunately, education and environment overcome many of the unfavorable results of heredity. In other words, regardless of inherited strains, a person may take on many worth-while characters or traits during the period of a lifetime. He may take music lessons, for instance, and acquire certain skills in music even though he may not have inherited a fondness for the subject. If he associates with right-minded people, he is likely to be right-minded himself, regardless of any inherited tendency. All

traits that come from the influence of environment are, of course, *acquired traits*. In general, they are not transmissible, although they may be effective over a long period of time.

Improvement by heredity. Human beings have no pedigrees which compare with those of domestic animals. The

A BARRIER TO UNDESIRABLE IMMIGRANTS
ELLIS ISLAND



Ewing Galloway

Ellis Island is situated in New York Harbor and is especially important because it is utilized by the United States government for examination of immigrants. Persons found to be diseased or mentally defective are sent back to the country from which they have come. Thus we are protected from unfavorable stock.

secret of improving the human species, however, lies in an improvement of human stock. In other words, it requires purification of stock to make more certain the transmission of favorable genes. The following measures will help:

1. All the intelligent members of society should become acquainted with the laws of heredity.
2. So far as possible the feeble-minded, criminal, and degenerate should be prevented from reproducing their kind.
3. Marriage between members of families of good mental and physical characteristics should be encouraged. Each

individual anticipating marriage should scan closely the characteristics and traits of the prospective mate to forestall the possibility of transmitting undesirable genes.

4. Immigrants should be carefully examined for physical and mental weaknesses, and admission denied to those of defective stock.
5. Good physical and mental health should be maintained. This means that we should ever strive to be physically fit and maintain a cheerful and hopeful outlook on life.

Agencies working toward social betterment. Today, as at no other time in our history, the general public is aroused to the necessity for improving social conditions. National, state, and city governments have created various agencies for such work. Among them are free clinics; special schools for mental defectives and the physically unfit; special courts for youthful offenders; and social service departments in connection with municipal courts to seek the causes of and to eliminate conditions that lead to crime. Private agencies as well, such as churches, settlement houses, and organized charities, are doing their part. These are only a few of the agencies helping to provide better opportunities for our citizens.

SUGGESTED ACTIVITIES

I. Self-Organization Summary

A. Variations and Their Relations to Heredity
1. Cite several examples of plant and animal variation.
2. Explain how organisms have come to possess certain definite characters.

B. The Laws of Heredity
1. What is the relation between chromosomes and genes?
2. Explain the process whereby chromosomes are reduced by one-half in the cells giving rise to eggs and sperms.
3. How are genes related to inheritance?
4. Pure-stock horned cattle are mated with pure-stock hornless cattle. By means of diagrams show how the genes combine to give the typical Mendelian ratio in the F_2 generation.

C. Causes of Variation
   1. What is meant by mutation?
   2. How may the occurrence of mutants be explained?

D. Plant and Animal Breeding
   1. How may a breeder of plants and animals make intelligent use of selection, hybridization, and mutation?
   2. What advantage does a breeder of plants have over a breeder of animals in the application of the Mendelian principles?
   3. Mention several plants and animals that have been improved by the process of breeding.

E. The Improvement of the Human Race
   1. Name three families presented in this unit and show how each is concerned with the problem of improving the human species.
   2. What inheritance danger is involved in inter-family marriages?
   3. How important are acquired traits in the improvement of life?
   4. Make a number of suggestions for improving the human species.

II. Laboratory Study

A. Show that the ratio in Mendel's law of segregation is the same as the ratio between heads and tails when two coins are tossed as many as a hundred times. If the number of heads (HH), heads and tails (HT), and tails (TT) are counted, they will be found to be approximately in the 1 : 2 : 1 ratio.

B. Show the relation of chance to Mendel's law of segregation by taking beads from a box. Prepare for the experiment by putting an equal number of beads of two different colors into the box. Draw two beads out at a time, and note the ratio of their various associations.

C. Demonstrate variation among human beings by measuring the circumference of the right wrist of each member of the class. Make a graph to show the variations.

III. Display Posters

A. Prepare a diagram of two unit characters showing the results for three generations of cross-breeding. Do not use the same unit characters discussed in the text.

B. Make a chart of a family pedigree other than those presented in the text.

IV. Special Reports

Read some of the following references and prepare special reports for the benefit of the class:

A. Vegetables our great-grandparents did not have
B. Fruits our great-grandparents did not have
C. How Mendel arrived at his conclusions
D. What we owe to Burbank
E. Pedigrees in royal families
F. The tragedy of the family of Nicholas II
G. How the farmer improves his crops through selection. How he improves his animals

REFERENCES[1]

1. Barnes, H. E. *The Story of Punishment.*
   This book describes prisons and the methods employed in handling prisoners.
2. Downing, Elliot R. *Elementary Eugenics.*
   a. Some famous racers and the problems they suggest, pp. 1–14
   b. Laws of heredity, pp. 23–37
   c. Are acquired modifications inheritable? pp. 77–91
   d. The inheritance of human characters, pp. 92–112
3. Ellwood, Charles A. *Sociology and Modern Social Problems.*
   a. Poverty and pauperism, pp. 299–324
   b. Crime and types of criminals, pp. 327–329
4. Huntington, Ellsworth. *Tomorrow's Children: The Goal of Eugenics.*
5. Jewett, Frances Gulick. *The Next Generation.*
   a. Fathers, mothers, and children, pp. 1–6
   b. Andalusian fowls, pp. 7–11
   c. Laws of inheritance put to use, pp. 26–33
6. Rice, Thurman B. *Racial Hygiene.*
   a. Good and bad stock in the human race, pp. 93–119
   b. Inherited diseases and defects, pp. 133–160
   c. Factors in marriage selection, pp. 254–266
   d. The defective individual, pp. 277–297
7. Ross, Edward. *The Outline of Sociology.*
   This book develops the topics of crime, poverty, and insanity.

[1] The pages listed here are those found in the editions indicated in the alphabetical list of references given at the end of this book.

8. Schmucker, Samuel. *Heredity and Parenthood.*
   a. A monk and his peas, pp. 15–32
   b. The stream of life, pp. 33–48
9. Wiggam, Albert Edward. *The Fruit of the Family Tree.*
   a. What twins tell about heredity, pp. 109–137
   b. Is disease inherited? pp. 155–172
   c. Is brain power inherited? pp. 173–208
   d. Measuring heredity in royalty, pp. 209–243
10. *Book of Popular Science, The.*
   a. Eugenics and the future, Vol. 15, pp. 5131–5138
   b. Society and crime, Vol. 12, pp. 4193–4200
11. *Compton's Pictured Encyclopedia.*
   a. Life's laws of inheritance, from plants to man, Vol. 6, pp. 283–286
   b. Improving plants and animals, Vol. 1, pp. 51–60
12. *New Wonder World, The.*
   a. Luther Burbank, plant breeder, Vol. 8, pp. 97–99
   b. Short necks or long, Vol. 10, pp. 268–273
13. *World Book Encyclopedia, The.*
   a. The laws of inheritance, pp. 3158–3161
   b. Plant creations of Luther Burbank, pp. 1024–1025

VISUAL AIDS

Films (16 mm.)

A. U. S. Department of Agriculture, Washington, D. C.
   1. Testing Seeds in Soil. 1 reel, silent, free.
   2. When the Cows Come Home. 1 reel, silent or sound, free. Shows the work and progress of dairy herd improvement

B. Indiana University, Extension Division, Bloomington, Indiana.
   1. Luther Burbank. 1 reel, silent, $1.00 per day. Shows the famous plant breeder at work on his experimental farm

C. Y. M. C. A. Motion Picture Bureau, New York City.
   1. Social Science. 1 reel, silent, $1.00 per day. Reveals conditions among retarded and maladjusted children, largely as photographed by the Institute of Juvenile Research, Chicago

Charts

Series	*Title*
Smalian Dobers Heredity	**Inheritance in Monohybrids**
	Inheritance in Dihybrids

UNIT FOURTEEN

CHANGING FORMS OF LIVING THINGS

SUGGESTIONS TO THE TEACHER

One of the most interesting studies in biology is the history of the earth as recorded in rocks. Students are always interested to learn how old the world really is, and how the different present-day plants and animals have descended from those of the past. There are many omissions in the records, but most forms of life can be traced back many, many years. Students will not only enjoy learning about the strange animals of the past but also will enjoy following through some of the changes that have resulted in the life forms upon the earth today.

This unit, then, discusses the changing forms of plants and animals. It includes a treatment of the evidences of change as shown in fossils, in vestigial structures, in embryological resemblances, in comparative anatomy, and in geographic distribution.

OBJECTIVES

I. Facts and principles

A. To study the methods whereby animals of the past have been preserved
B. To understand how the approximate age of the earth has been calculated
C. To observe life sequence as evidenced in rock strata
D. To understand the geological time scale
E. To study some of the evidences which clearly show that living forms change
F. To speculate upon the theories that seek to explain the methods of change

II. Attitudes

A. To appreciate the fact that living forms are not permanently fixed but that slight changes are continually taking place
B. To desire fuller knowledge of the life forms of the past for a better understanding of those of the present
C. To develop a hopeful outlook as a result of the continual improvement of life forms

UNIT FOURTEEN

CHANGING FORMS OF LIVING THINGS

A PREHISTORIC FOREST

Courtesy Field Museum of Natural History

It was during the Carboniferous Period that nature's coal supply was formed from plants like these. Dense growths of such plants prevailed upon the earth.

THE PASSING OF THE DINOSAURS

PREVIEW

Ages ago there lived upon the earth reptile monsters called *dinosaurs* (dī′nô-sôrs) that ranged over all of the continents, except perhaps Antarctica. Many of these giant animals measured from sixty to one hundred feet in length and weighed from forty to fifty tons. Some were strangely unbalanced creatures, possessing small heads, long necks, weak front legs, and tails twenty to fifty feet in length. Others were covered with spiny scales and bony plates, their heads bore huge horns, and ugly crests or spines extended from their tails. Today, of course, we can see only reproductions of these animals. Scientists, using remnants of skeletons and data from rocks, have reproduced many weird specimens, some of which make us feel "creepy" in their presence.

WHEN THE DINOSAURS RULED THE EARTH

Courtesy Compton's *Pictured Encyclopedia*

An artist's conception of a battle of prehistoric times. The allosaur, being much quicker of movement, is poised ready to spring upon the huge brontosaur. The allosaur was a flesh-eating animal, whereas the brontosaur lived upon plants. Both of these creatures belong to the famous dinosaur group. The stars on the map at the top indicate places in the United States and Canada where fossils of dinosaurs have been found.

Let us turn back the pages of time and observe some of the conditions that existed on the earth when these great creatures roamed over its surface. Some of them were herbivorous, subsisting only on plants; others were carnivorous, eating only the flesh of herbivorous animals. They killed their victims by sinking their great sharp teeth into their necks. To keep such huge bulks of flesh and bone alive, enormous quantities of food were necessary. Plant food was obtained from the abundant vegetation that covered much of the earth. A warm climate, plentiful rainfall, and low, swampy ground produced a thick, tangled growth of plants. Ferns as large as trees, giant palms and horsetails, and thick masses of aquatic plants flourished.

For many million years the dinosaur monsters roamed among the giant ferns, lolled in the swamps, and fought to kill one another. Then certain changes apparently occurred in their environment that made it difficult for them to live and they passed out of existence. Tremors and upheavals occurred in the crust of the earth, resulting in great changes in surface and climate.

After the passing of the dinosaurs, new plants and new animals better adapted to the new conditions of environment gradually came into being. Seed-bearing plants, modern trees, and mammals, such as horses, elephants, dogs, and man, gradually appeared upon the face of the earth. All forms of life, however, have undergone numerous changes and are still undergoing changes today. They change as they make adaptations to the conditions of their environment. The story of the changing forms of living things involves a discussion of the following problems.

PROBLEMS

1. **What does the past reveal regarding the life of the world?**
2. **How do we know that living forms have changed over long periods of time?**
3. **What theories seek to explain how living forms change?**

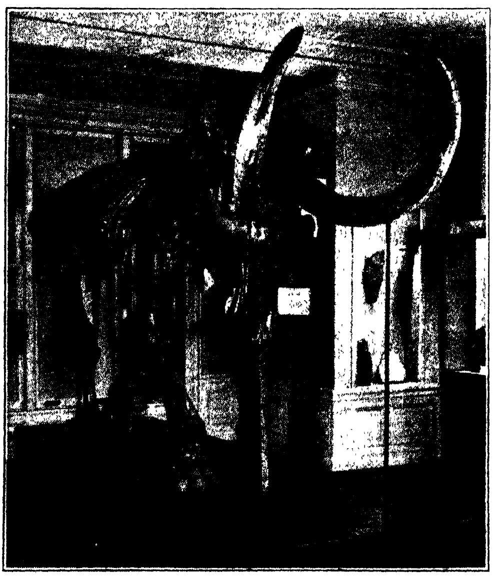
Problem 1. What does the past reveal regarding the life of the world?

THE PRESERVATION OF ANIMALS OF THE PAST

The proof that living forms constantly change comes partly from the discovery of preserved specimens of early life and the records that plants and animals have left in ancient rocks. We shall first consider the evidence that comes from preserved specimens. In general, these specimens have been saved by three processes:

1. By freezing in ice as in frigid regions
2. By chemical action, especially of such substances or compounds as oil and amber
3. By mineralization, a process more commonly known as *petrifaction* (pĕt′rĭ-făk′shŭn)

PREHISTORIC RELATIVE OF THE ELEPHANT—THE MASTODON



Courtesy Cleveland Museum of Natural History

The extinct mastodon differs from the mammoth, also extinct, and existing elephants chiefly in the structure of teeth.

Ancient animals in "cold storage." Within recent years the remains of ancient animals have been found in the frigid regions of the North, principally in Siberia, where the land is covered with snow and ice. Entire bodies frequently have been found with their skin, hair, and flesh just as they were at the time of death. In 1901 a huge *mammoth* (prehistoric elephant) was found about sixty

miles north of the Arctic Circle. Except for a portion of its trunk and some hair on its back, the animal was intact.

Animals preserved in oil and amber. The bodies of many ancient animals have been preserved in natural deposits of oil and resin. A prehistoric rhinoceros, for instance, was found in Poland in 1907, the remains of which had been buried in soil saturated with petroleum.

Several thousand species of insects, spiders, and crustaceans and several hundred species of plants have been found in amber. When these organisms died, their bodies were covered with resin that exuded from the pines or other coniferous trees. When the resin hardened, it turned to amber, in which the bodies fossilized. The most famous deposits of amber containing fossils are those along the coast of the Baltic Sea.

Petrified plants and animals. A large part of our information about prehistoric life is derived from organisms that have been found in a state of petrification, or mineralization. In this case the tissues of the plants and animals have gradually been replaced by such substances as iron oxide, lime, or silica.

Gaining knowledge of the past from molds, footprints, and trails. Plant and animal forms of the past are sometimes revealed by the impressions their bodies have left in rocks. It is probable that these animals were accidentally buried in soft mud. Afterward the surrounding mud hardened, thus forming molds or casts which kept their shape after the bodies of the animals had decayed. From these molds or casts exact models of prehistoric forms of life may be reconstructed. Footprints and trails of various animals have also been found (see following page). These doubtless have resulted from the hardening of mud in which the early creatures walked.

Fossil Remains

Numerous layers of rocks. We learn most about the early forms of life upon the earth from fossils and impressions in rock. These fossils are found only in *sedimentary rock,* or that which has been formed from sediment composed of weathered rock material deposited in layers at the bottom of

bodies of water. This rock sometimes extends to great depths below the surface, often many miles. We can observe the nature of the layers by looking at the exposed faces of limestone or sandstone cliffs. These layers were deposited over a long period of time—millions and millions of years. Unless an upheaval of some kind has occurred, the lowest layer is the oldest and the top layer the newest.

TRACKS OF ANCIENT MONSTERS

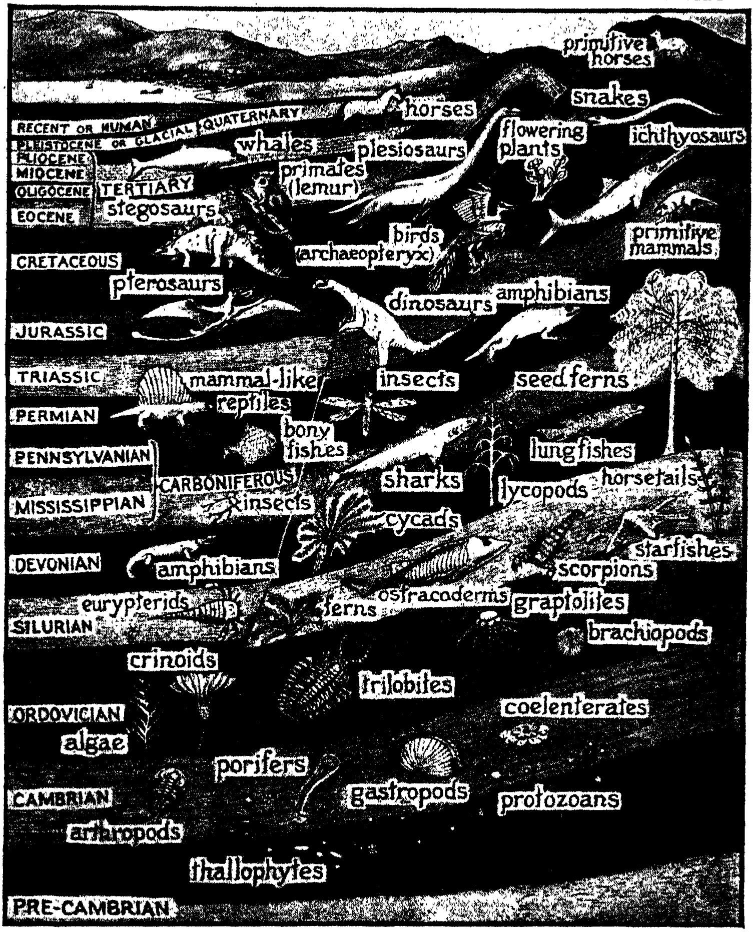
Courtesy American Museum of Natural History

Another evidence of the animal life of prehistoric times is furnished by tracks. Just as Bertillon studies of fingerprints identify human beings, so do the footprints in rock help to identify animals that formerly lived upon the earth.

Life forms shown by the rock layers. The deepest and oldest layers of rock, those that date back to remote times, bear no fossil evidence of life upon the earth. Certain strata, however, near the lowest and hence nearly as old, yield fossils of primitive forms of life, such as invertebrate animals. Slightly higher and later strata yield fossils of fishes. The strata from there on down to the present time yield fossils of changing forms of vertebrates. A fossil sequence in the strata similar to that for animals occurs for plants. The oldest rock strata contain fossils of very simple plants, such as the algae. The later, or coal-bearing, strata contain fossils of ferns, and still later strata show the seed-bearing plants.

A perfect sequence of rock strata and their corresponding fossils cannot be found everywhere. Earthquakes, volcanic action, and weathering have mixed certain strata, or caused

A STORY OF LIFE AS REVEALED BY THE ROCKS



This is a diagrammatic representation of rock strata. The older, which are usually the lower, strata contain fossils of the more primitive forms of life. Note that in the drawing primitive horses appear higher than modern horses. This is because earth movements have disturbed the strata and changed their original position.

the omission of certain others. In general, however, the sequence of the strata and that of the fossils correspond.

The nature of the fossils in the lower strata of rock shows that some of the present land areas of the earth were formerly

covered by water. All the fossils are of animals that could live only in the sea. For example, fossils of *crinoids* (krī′noidz) have been found in the sandstone hills of Kansas. Such animals could never have lived in this part of the world had not the region been a part of the sea.

The radium time clock. By a study of the rate of sedimentation and the behavior of radium, scientists have been able to estimate the approximate number of years ago that various plants and animals lived upon the earth. Radium, a product of uranium, is composed of tiny explosive atoms. As a result of the explosive changes that occur in these atoms, certain other elements are formed. Lead is one of these elements. The rate at which a given quantity of radium will produce a given quantity of lead is known. Thus if both radium and lead are found in a certain rock stratum, the age of that stratum can be computed. By using this method of computation, scientists estimate that the lowest and oldest rock stratum that bears fossils is from one-half billion to one billion years old.

THE GEOLOGICAL TIME SCALE

The science which involves a study of the history of life as told by fossils is called *paleontology* (pā′lē-ŏn-tŏl′ō-jĭ). That which involves a study of the history of the earth as told by rocks is called *geology*. These two fields of science have worked together in giving us the story of the past as it relates to the earth and the life upon the earth. Scientists in these fields have grouped the millions of years into long expanses of time known as *eras*. These they have subdivided into *periods*, and the periods into *epochs*.

The time scale a history of life forms. Under the environmental conditions that existed during given periods of rock formation, only certain plants and animals lived upon the earth. The fossils of these plants and animals were formed in the sediments that make up the rock strata of these periods. When environmental changes occurred, new forms of life adapted to the new conditions slowly came into existence. The story of "The Passing of the Dinosaurs" illustrates what

probably took place during the transition from one era to another. It does not follow, however, that all the species of plants and animals of a given era passed out of existence at the close of the era. Only those that were very poorly adapted to the newer environmental conditions became extinct. For example, certain one-celled plants and animals now living seem to resemble closely those that existed from the very beginning. The dinosaurs became extinct at the end of the Mesozoic Era, but certain palms and ferns of the same era continued to live in the next.

The table on the following pages is a chart of past ages as arranged by geologists and paleontologists. Certain simplifications and approximations, however, have been made to make it better adapted to our use.

Problem 2. How do we know that living forms have changed over long periods of time?

A number of facts seem to support the theory that present forms of life have come about as a result of gradual changes in form and structure down through the ages. These facts are enumerated below and discussed at length on later pages.

1. Fossils give conclusive evidence of changes.
2. Certain changes resulted from modified geographical conditions that have affected the distribution of plants and animals. Redistribution has usually resulted in adjustments that have affected the nature of life.
3. Changes in anatomy have occurred to meet the conditions of the modes of living, as on land, in water, and in air.
4. Practically all the higher forms of animals have a number of vestigial (vĕs-tĭj'ĭ-ăl) or rudimentary useless parts, indicating changes from former useful parts.
5. Developing mammal embryos indicate that living forms change.

Changes indicated by fossils. The following geological time scale shows that many changes have occurred in the forms of life down through the ages. According to this scale the

GEOLOGICAL TIME SCALE—DESCRIPTIVE

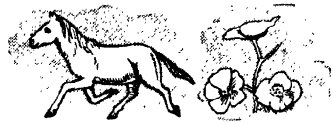
Eras	Periods and Epochs	Years Ago	Changes in Living Forms
Cenozoic	Quarternary: Recent Pelistocene or Glacial	1,000,000	Many mammals of gigantic size which later became extinct
	Tertiary: Pliocene Miocene Oligocene Eocene	55,000,000	Modern tree families appeared Birds modern, but a few still had teeth Reptiles modern in appearance First primates appeared
Mesozoic	Cretaceous Jurassic Triassic	120,000,000 155,000,000 190,000,000	Highest insects appeared, such as butterflies, bees, ants Earliest flowering plants appeared Earliest mammals appeared, dividing into groups by end of era Giant reptiles appeared, became dominant forms. Extinct by end of era Giant amphibians became extinct
Paleozoic	Permian	215,000,000	Reptiles increased in size Amphibians increased in size and species Trilobites became extinct First traces of cycads and conifers (orders of gymnosperms) Tree ferns abundant Pteridophytes leading plants
	Carboniferous: Pennsylvanian Mississippian Devonian	550,000,000 350,000,000	Insects became abundant Lycopods (club mosses) were largest trees Earliest amphibians appeared Earliest lungfishes and bony fishes appeared Earliest gymnosperms appeared Earliest seed plants appeared (seed ferns) Pteridophytes abundant
	Silurian Ordovician	390,000,000 480,000,000	Armored fishes appeared Crustaceans divided into many species Earliest arachnids appeared (Eurypterids) Earliest known land plants and animals appeared (pteridophytes and scorpions) Earliest traces of vertebrates Mollusks and brachiopods abundant Trilobites less important Great diversity of life forms
	Cambrian	550,000,000	Mollusks and brachiopods (mollusk-like forms) became important Earliest traces of echinoderms (sea cucumbers, cystoids) Earliest traces of coelenterates (jellyfish, graptolites, corals)
Proterozoic Era			Earliest traces of worms, sponges, and trilobites (crustaceans) Slight diversity of life forms
Archeozoic Era			Beginning of life

GEOLOGICAL TIME SCALE—ILLUSTRATED

DOMINATING FORMS OF LIFE

Cultivated plants
Domestic animals
Man

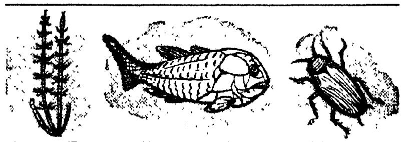
Mammals
Flowering plants



Gymnosperms
(cycads and conifers)
Giant reptiles

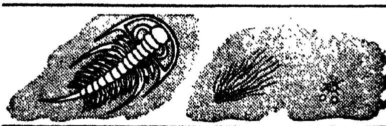
Tree ferns
Amphibians

Horsetails
Fishes
Insects



Mollusks, particularly cephalopods
Algae
Brachiopods

Trilobites
Algae
Bacteria



Simple plants
Simple invertebrates

Single-celled plants and
animals. No fossils
definitely identified

THE FIRST AVIATORS

Courtesy *Book of Popular Science* by permission of the Grolier Society

These winged reptiles were the first vertebrate aviators.

animals of very early times were simple shelled invertebrates that lived in the water. Next mollusks and mollusk-like forms developed. Then came the first land plants and animals, and still later, amphibians. The early plants were of the spore-bearing type, and it was many ages before flowering plants and modern trees appeared.

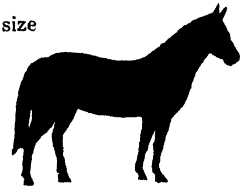
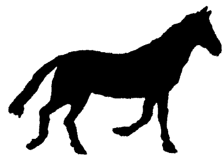
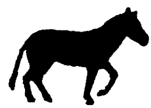
It was largely during the period of spore-bearing plants that the dinosaurs and other giant reptiles inhabited the earth. Some of these reptiles could fly and had huge batlike wings that spread twenty feet or more. Their bodies were covered with scales and bony crests rather than feathers. Fossils indicate that it was from such flying reptiles that birds gradually developed. Some of the early forms of birds had teeth, long bony tails, and scalelike coverings, there being only a few patches of feathers here and there on the wings and tails.

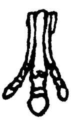
The first mammals probably did not appear until after the extinction of the giant reptiles and the rise of flowering plants. In the geological scale they are the youngest of animal forms. This seems strange because they are also the most highly developed. The fossils tell some interesting stories of the changes that have taken place in mammals from earliest times. Sufficient fossils of such animals as the horse, camel, and elephant, for instance, have been found to show clearly how they have taken on their present forms and structures. Since these records are fairly complete, they are sometimes spoken of as *fossil pedigrees*.

The probable origin of the modern horse. The fossil pedigree of the horse provides an excellent illustration of the process by which a species of animal undergoes changes over a long period of time. The modern horse, we find, is vastly different from its early ancestor. The story of its development, which has been determined within recent years through the discovery of fossil remains in the United States, is one of the most interesting ever devised.

The story of the horse covers millions of years, beginning with the Eocene (ē′ō-sēn) period, when most mammals were small. One of these mammals has been identified as the ancestor of the modern horse. For scientific purposes, it has been called Eohippus (ē′ō-hĭp′ŭs), which means "dawn horse." According to the fossils, it was only about the size of a fox terrier dog. On each front foot it had four toes and a splint of a fifth, and on each hind foot, three toes. It had small, short-crowned teeth, adapted for chewing many kinds of food.

Eohippus was so different from the modern horse that we might be tempted to doubt its ancestral connection. However, the accumulated evidence shows an unbroken line of descent from Eohippus to the modern animal. The fossils in successive layers of rocks show how the ancestors increased in size, developed a larger middle toe as the other toes dwindled in size, and acquired longer and more complex teeth. The table on the following pages presents a detailed picture of the transformation that has taken place.

Name of Horse	Period or Epoch	Size
Equus	Pleistocene	Modern size 
Pliohippus	Pliocene	Almost modern size 
Protohippus	Lower Pliocene	Size of donkey 
Miohippus	Miocene	Larger than sheep 
Mesohippus	Oligocene	Size of sheep 
Orohippus	Middle Eocene	Size of large dog 
Eohippus	Lower Eocene	Size of fox terrier dog 

FRONT FEET	HIND FEET	TEETH
One center toe in form of rounded hoof; two side splints 	One center toe in form of rounded hoof; two side splints 	Long-crowned teeth with ridges; more cement 
One center toe; two side splints 	One center toe; two side splints 	Longer teeth with ridges; more cement 
Three toes; animal probably walked on center toe 	Three toes; animal probably walked on center toe 	Longer teeth with ridges; some cement between ridges 
Three toes with center toe the largest; splint of fourth toe 	Three toes with center toe the largest 	Longer teeth with ridges; no cement 
Three toes with center toe the largest; splint of fourth toe 	Three toes with center toe the largest 	Longer teeth with more ridges; no cement 
Four toes 	Three toes 	Longer teeth with a few ridges; no cement 
Four toes; splint of fifth toe 	Three toes 	Short-crowned teeth; no cement 

Changes resulting from adjustments to changed geographical conditions. In the past, as at present, the geographical factors of climate and the nature of the earth's surface have greatly affected the distribution of life forms. Fossils show that the distribution today is very different from what it was down through the ages of the past. In some places there has been a change in climate. Greenland and Iceland, for example, were once warm enough to support many plants and animals. Then came a great glacial ice sheet that covered all the north polar region. This ice sheet gradually extended southward, driving the plants and animals before it. Thus today some of the forms of life in central North America, Europe, and Asia are similar to those that once existed near the North Pole.

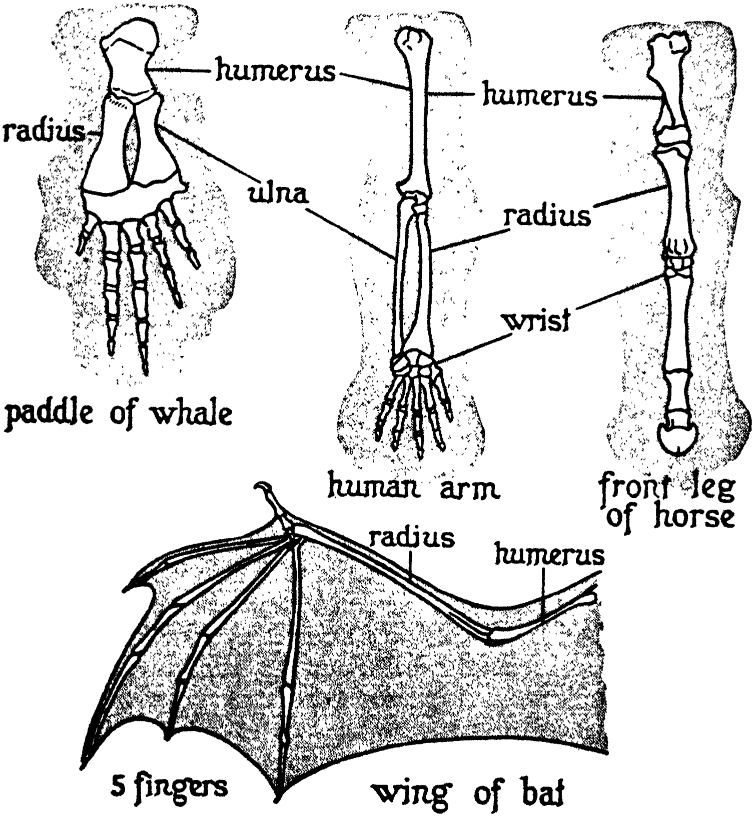
In other places the surface of the earth has changed. The continents of North America and Asia, for example, were probably once united, and Australia was a part of the continent of Asia. As various upheavals have occurred in the crust of the earth, water has sometimes appeared where there was land before, and land has appeared where there was water. Consequently some regions now dry and barren were once low and swampy, and vice versa. The Gobi Desert is an example. Though barren today, at the time of dinosaurs this region supported a dense vegetation and many great reptiles.

The upheavals or depressions in the earth's surface have brought about the isolation of certain regions so that they have developed distinctive flora and fauna. Australia, for instance, presents an interesting field for the study of life because of its primitive forms. This island continent was cut off from Asia before the modern mammals came into existence. Hence only primitive mammals are native to Australia, modern mammals never having developed as they have in Europe, Asia, and America. A few of the mammals in Australia lay eggs. One of these, the duckbill, has a beak and feet that somewhat resemble those of birds. Then there are the many marsupials, slightly higher in type, that carry their young around in pouches. These include such animals as the kangaroo, wombat, koala, and Tasmanian wolf.

Thus life on the earth has been continually affected by the geographic conditions of environment. As these conditions have changed, life also has changed. Barriers, largely water, which have prevented the intermingling of various forms of life, have caused many isolated regions to develop a flora and fauna all their own. This is particularly true of Australia and various islands in the Australian realm.

Changes to suit mode of living. The skeletons of amphibians, reptiles, birds, and even mammals are very much alike

SIMILARITY IN BONES



How do these structural comparisons indicate that living forms have changed?

in their general shape and arrangement. In each of the classes, however, certain adaptations or changes have been made according to the mode of living. Thus the mammals have developed good legs with which to walk or run upon the ground, the birds have developed wings with which to fly, and fish have developed fins with which to swim. All these parts are modifications of corresponding appendages.

Changes indicated by vestigial structures. Nearly every higher form of life has certain rudimentary structures that are wholly or partly useless. Such rudimentary parts are said to be *vestigial* (vĕs-tĭj′ĭ-ăl). In the modern horse, for example, the two side splints on each of its feet are vestigial. They once were used as toes, but no longer serve any apparent purpose. The whale and the porpoise still have vestigial pelvic bones, although they no longer need pelvic limbs.

Changes indicated in mammal embryos. Some of the changes through which life forms have passed seem to be revealed sometimes in a study of embryos. In other words, a developing embryo sometimes seems to pass through stages in which certain structures appear that were once possessed and used by more primitive animals. This manifestation, known as *recapitulation,* presents some interesting occurrences.

The mammal embryo is often used to illustrate the principle of recapitulation. At first, for example, gill openings appear just as if a fish were developing. The openings do not develop, however, and lungs appear instead. Thus the mammal embryo seems to repeat the life history of the amphibians, which breathe first by means of gills and later by the use of lungs. The mammal embryo also seems to recapitulate some of the structures of primitive hearts. The embryonic heart, for example, at first is tubelike, but later divides into two chambers, an auricle and a ventricle. In this respect it follows the development of the heart of a fish. Later the auricle divides into two parts—a right and a left auricle—and a typical three-chambered amphibian heart is produced. Finally, the ventricle divides into right and left ventricle, and the four-chambered heart is completed.

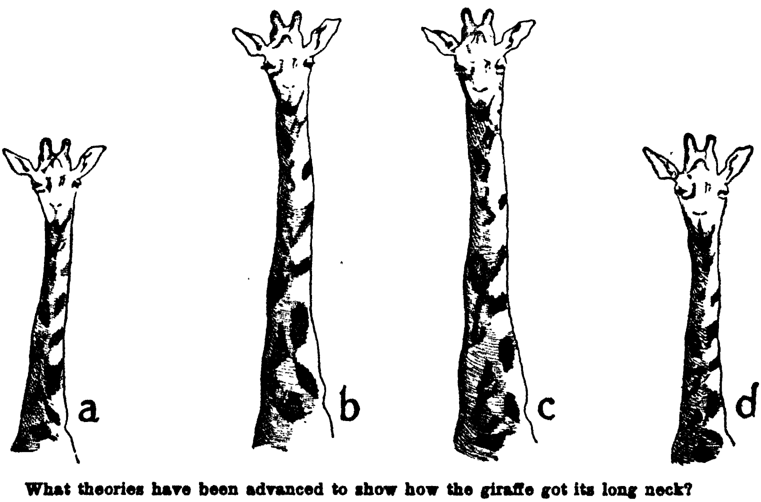
Problem 3. What theories seek to explain how living forms change?

Ever since it was first definitely known that changes take place in the form and structure of living things, scientists have sought a true explanation of the way in which they occur. Various theories have been advanced. It is impossible, of course, to go into a discussion of all these theories, but we shall briefly consider a few of the more important ones.

THE THEORY OF THE INHERITANCE OF ACQUIRED CHARACTERS

One of the earliest explanations was offered by Lamarck (1744–1829), who believed that organisms acquire through

THE SUBJECT OF MANY SCIENTIFIC DISCUSSIONS
THE LONG-NECKED GIRAFFE



What theories have been advanced to show how the giraffe got its long neck?
a. Neck of original giraffe
b. Neck lengthened after constant feeding from trees (according to Lamarck)
c. Acquired neck passed on to offspring by inheritance (according to Lamarck)
d. Neck of offspring according to Weismann, who believed that acquired characters are not transmitted

inheritance certain characters that result from the use or disuse of various organs or parts of the body. Thus, according to his theory, long-necked giraffes came from short-necked

animals. When grass became scarce, the original giraffes began to eat the leaves of trees. The constant reaching upward led to a modification of form and structure that was passed along from generation to generation until finally the present long-necked giraffes appeared. Thus, according to Lamarck, the parts of the body that are used continue to function and they may become even more highly developed, while parts that are not used become functionless and tend to disappear. In this way his theory explained the presence of vestigial structures.

Most scientists today, however, do not accept Lamarck's theory of the inheritance of acquired characters. Reaching for food, they argue, has no effect on genes; and it is by the genes, of course, that characters are transmitted. Weismann, according to the description on page 644, conducted certain experiments with rats in an attempt to produce a short-tailed species. Although he cut off the tails through many generations, at the close of the experiment the rats were growing tails just as long as those in the beginning.

THE THEORY OF NATURAL SELECTION

The second great theory attempting to explain changing forms was advanced by Darwin (1809–1882), and is sometimes called the theory of *natural selection* or the "survival of the fittest." He argued that in the general struggle for existence the individuals best fitted to their environment have the best chance to live and reproduce their kind. In general, his explanation may be considered as including the following steps:

1. There is always an overproduction of offspring—more than can possibly survive.
2. A great struggle for existence takes place in which most of the offspring of each species must perish.
3. Many variations occur among the offspring, some being better adapted to the environment than others.
4. The fittest survive.
5. The fittest pass on to their offspring the characters that mark their superiority.

According to Darwin's theory the giraffe obtained its long neck because only those giraffes with the longest necks could reach sufficient food to keep alive. In other words, only animals with long necks could adapt themselves to their environment, and hence survive. Darwin's theory, however, like that of Lamarck, is no longer generally accepted in its entirety. In the first place, we know from our own observation that in the struggle for existence many unfit as well as the fittest survive. In the second place, Darwin's theory does not explain the vestigial structures found in many plants and animals. In the third place, his theory does not take into account mutations, which, as we have already learned, spring up from time to time and produce permanent departures from old characters. In the fourth place, the operation of the laws of inheritance is such that the fittest animals do not always pass their characteristics on to their descendants. Thus long-necked giraffes might become the parents of short-necked giraffes.

THE MUTATION THEORY

In the theory of *mutation*, advanced by Hugo de Vries, we have the best explanation of how living forms change and produce new species. Briefly, he maintains that *sports* or *mutants* appear from time to time with characters completely different from the usual ones of a given species. These departures are transmitted to succeeding generations because they are caused by changes in the genes.

Mutation is the latest and most acceptable theory of the cause of changes in plants and animals. A full explanation is given in Unit Thirteen.

MILLIONS OF YEARS REQUIRED FOR GREAT CHANGES TO OCCUR

In Unit Thirteen it is pointed out that many changes in plants and animals, called *variations*, occur within a comparatively short time. Burbank, for instance, brought about thousands of variations during a lifetime. It usually requires much longer, however, for great changes to occur—the changes we

have been considering in this unit. Thus it took ages for fish, amphibians, reptiles, birds, and mammals to emerge. Our own lives are so short that we can never fully comprehend the gradual process by which nature changes the living things of the earth. The most we can realize is that there is a great scheme of life which has operated throughout the ages — a scheme whose workings we are only just beginning to understand,

> Seeing it good as when God first saw
> And gave it the weight of His will for law.
>
> — BLISS CARMAN

SUGGESTED ACTIVITIES

I. Self-Organization Summary

A. Records of the Past

1. Explain three ways in which the bodies of prehistoric plants and animals have been preserved.
2. What are fossils? How were they probably formed?
3. Explain the geological time scale and the action of radium as a basis for estimating time.
4. What evidences do the various rock strata present that life started with simple forms and has gradually risen to higher and higher levels?

B. Evidences of Change in Living Forms

1. How do fossils indicate that changes have taken place in the form and structure of living things? Illustrate by means of the modern horse.
2. How have changes in life forms come about as the result of changes in geographical conditions?
3. What adaptations have been made to different modes of living? Explain by example.
4. What are vestigial structures? How do they point to changes?

C. Theories That Seek to Explain Changes in Living Forms

1. Explain the theory of the inheritance of acquired characters and point out its weakness.
2. What is meant by the theory of natural selection? Wherein does it fail to explain changes satisfactorily?
3. Explain the theory of mutation and tell why it is more plausible than other theories.

II. Laboratory Study

A. Examine specimens from some of the various rock strata and note the difference in composition.
B. Examine casts and models for an understanding of the way in which fossils appear in rock strata.
C. Visit near-by cliffs for the purpose of examining layers of rock.
D. Compare the form and structure of the wings of a bird, the fins of a fish, and the forelegs of a mammal.
E. Compare the skeletons of fish, amphibians, reptiles, birds, and mammals and note their similarity of form regardless of the different modes of living.

III. Display Posters

A. Prepare a chart to show the distribution of flora and fauna in the various geological periods.
B. Prepare a chart to show the fossil pedigree of the camel and of the elephant.
C. Collect pictures of prehistoric animals and mount them on a large cardboard.
D. Collect pictures of prehistoric plants.

IV. Special Reports

Read some of the references at the end of this unit or others of your own selection and prepare special reports. The following suggested topics may interest you:

A. How coal was formed
B. The flora and faunà of the Galápagos Islands
C. Other creatures that lived at the time of the dinosaurs
D. Geological expeditions into the Gobi Desert
E. The rise of the modern horse

REFERENCES[1]

1. Bean, Robert Bennett. *The Races of Man.*
   a. The formation of races, pp. 40–43
   b. The dispersal of man, pp. 43–54
   c. Classification of man, pp. 97–115

[1] The pages listed here are those found in the editions indicated in the alphabetical list of references given at the end of this book.

2. Branson, E. B., and Tarr, W. A. *Introduction to Geology.*
   a. Volcanism and igneous rock, pp. 10–76
   b. Sedimentary rocks, pp. 173–208
   c. Geologic eras and their life, pp. 306–457
3. Jewett, Frances Gulick. *The Next Generation.*
   a. A few of Darwin's facts, pp. 43–55
   b. Evidences of change, pp. 64–71
4. Mather, Kirtley F. *Sons of the Earth.*
   a. Geological history of the earth and the radium time scale, pp. 3–100
5. Whitnall, Harold O. *A Parade of Ancient Animals.*
   a. Reptiles and how they arrived, pp. 28–34
   b. Birds that forgot how to fly, pp. 92–98
   c. The hairy ones that were smarter, pp. 98–103
   d. Camels and their queer relatives, pp. 122–126
6. *Book of Popular Science, The.*
   a. Living creatures on the borderline, Vol. 1, pp. 355–368
   b. Earth's autobiography, Vol. 2, pp. 601–611
7. *Compton's Pictured Encyclopedia.*
   a. Giant monsters of long ago, Vol. 1, pp. 204–210
   b. Unearthing the fossils, Vol. 5, pp. 161–164
8. *New Wonder World, The.*
   a. Animals before man, Vol. 1, pp. 275–288
   b. On the trail of man, Vol. 1, pp. 392–400
9. *World Book Encyclopedia, The.*
   a. Geological history of the earth, pp. 2732–2745
   b. Outline of man's early history, Guide, p. 8013

VISUAL AIDS

FILMS (16 mm.)

A. Y. M. C. A. Motion Picture Bureau, New York City.
   1. Cycle of Erosion. 1 reel, silent, $1.00 per day.
   2. Digging Up the Past. 1 reel, silent, free.

B. F. C. Pictures Corporation, 505 Pearl Street, Buffalo, New York.
   1. Birth of the Earth. 5 reels, silent, apply for rental. Tells the story of creation in a simple or nontechnical manner

C. National Park Service, Washington, D. C.
   1. Looking Back through the Ages. 2 reels, silent, $8.65.

APPENDIX

AN EXTENSIVE CLASSIFICATION OF PLANTS AND ANIMALS

The following classification is provided to give a fairly complete picture of plant and animal life. It is impossible and impracticable, of course, in a book of this sort to include all of the groups from the highest to the lowest in each phylum. Furthermore, only the more important plants and animals of any group are given as examples. Then, too, the classification may be different from that given in some references, because botanists and zoölogists are not in complete agreement on the details of classification. One might find, for instance, certain orders listed as classes by some authors, or a questionable microscopic plant listed as an animal, all depending upon the point of view. The authors have endeavored to simplify the classification as much as possible, keeping it sufficiently scientific for practical uses. Where it is consistent with modern usage, the English forms of scientific terms are used instead of the Latin.

The members of the plant and animal kingdoms are sorted into a descending series of groups as follows:

- Phyla
  - Subphyla
    - Classes
      - Orders
        - Families
          - Genera
            - Species
              - Varieties

THE PLANT KINGDOM

Phyla

I. THALLOPHYTES (thăl′ō-fīts)—80,000 species. The simplest forms of plant life. No true stems, leaves, or roots. Reproduction commonly asexual by cell division and by spores, and also sexual by gametes. Plants range from one-celled and microscopic to large, many-celled forms.

Subphyla

A. ALGAE (ăl′jē)—10,000 species. Mostly water plants. All contain the green coloring matter chlorophyll. Colors besides green also present.

Classes

1. Green Algae. Examples: Spirogyra, Vaucheria, Protococcus.
2. Red Algae. Example: Corallina.
3. Brown Algae. Examples: sargassum, kelps.
4. Blue-green Algae. Example: Nostoc.

B. FUNGI (fŭn′jī)—64,000 species. Plants have no chlorophyll; hence they are either parasites or saprophytes.

Typical Classes

1. Schizophytes (skĭz′ô-fīts). Example: bacteria.
2. Phycomycetes (fī′kô-mī-sē′tēz). The algal fungi. Examples: black mold, blights.
3. Ascomycetes (ăs′kô-mī-sē′tēz). The sac fungi. Examples: yeasts, mildews.
4. Basidiomycetes (bȧ-sĭd′ĭ-ô-mī-sē′tēz). The club fungi. Examples: rusts, smuts, mushrooms.
5. Lichens (lī′kĕnz)—5,600 species. Their classification is uncertain because they are composed of both algae and fungi. Examples: reindeer lichen, "old man's beard," crusty lichens.

II. BRYOPHYTES (brī′ô-fīts)—15,000 species. These plants have probably arisen from green algae that have changed their place of living from water to land. They have no vascular system. Their life history includes a distinct *alternation of asexual and sexual generations.* The conspicuous plant body is the *gametophyte.*

Classes

1. Liverworts. Example: Marchantia.
2. Mosses. Example: pigeon-wheat moss.

III. PTERIDOPHYTES (tĕr′ĭ-dô-fīts′)—5,000 species. Definite sap- and food-conducting tubes (*vascular system*) first appear in this phylum. These plants have an *alternation of generations.* The large leafy plant is the *sporophyte.*

Classes

1. Ferns.
2. Club Mosses.
3. Horsetails.

IV. SPERMATOPHYTES (spûr′mȧ-tô-fīts′)—150,000 species. First plant phylum to reproduce by seeds. The leafy plant is the *sporophyte,* the *gametophyte* being inconspicuous.

Subphyla

A. GYMNOSPERMS (jĭm′nô-spûrmz)—500 species. Mostly cone-bearing plants. Seeds exposed or naked. Examples: cycads, pines, Ginkgo.

B. ANGIOSPERMS (ăn′jĭ-ô-spûrmz). The flowering plants. Seeds inclosed in an ovary.

Classes

1. MONOCOTYLEDONS (mŏn′ô-kŏt′ĭ-lē′dŭnz)—35,000 species. Embryos with *one cotyledon.* Parts of the flowers in threes or sixes. Leaves parallel-veined. Vascular bundles scattered throughout the stem.

Typical Orders

a. Graminales (grăm′ĭ-nā′lēz).

Typical Families

(1) Gramineae (grȧ-mĭn′ê-ē). Grass family.

Typical Genus

(*a*) Zea (zē′ȧ).

Species

i. *Mays* or corn.

(*b*) Triticum (trĭt′ĭ-kŭm). Example: wheat.
(*c*) Secale (sê-kā′lē). Example: rye.

(2) Cyperaceae (sī′pẽr-ā′sê-ē). Sedge family.

Typical Genus

(*a*) Carex (kā′rĕks). Example: sedge.

b Liliales (lĭl′ĭ-āl′ēz).

Typical Families

(1) Liliaceae (lĭl′ĭ-ā′sê-ē). Lily family.

Typical Genera

(*a*) Lilium (lĭl′ĭ-ŭm). Example: common lily.
(*b*) Tulipa (tū′lĭ-pȧ). Example: tulip.

(2) Juncaceae (jŭŋ-kā′sê-ē). Rush family.

Typical Genus

(*a*) Juncus (jŭŋ′kŭs). Example: rush.

2. DICOTYLEDONS (dī′kŏt′ĭ-lē′dŭnz)—115,000 species. Embryos with *two cotyledons.* Parts of the flowers in fours or fives. Leaves netted-veined. Vascular area of stem surrounding a central pith.

Typical Order

a. Rosales (rō-zā'lēz).

Typical Families

(1) Rosaceae (rō-zā'sē-ē). Rose family.

Typical Genera

(*a*) Rosa (rō'zȧ). Example: rose.
(*b*) Rubus (ro͞o'bŭs). Example: raspberry.
(*c*) Pyrus (pī'rŭs). Example: apple.
(*d*) Crataegus (krȧ-tē'gŭs). Example: hawthorn.

(2) Leguminoseae (lē-gū'mĭ-nō'sē-ē). Legume family.

Typical Genera

(*a*) Phaseolus (fā-sē-ō'lŭs). Example: bean.
(*b*) Pisum (pī-sŭm). Example: pea.
(*c*) Trifolium (trī-fō'lĭ-ŭm). Example: clover.
(*d*) Gleditsia (glē-dĭt'sĭ-ȧ). Example: honey locust.

THE ANIMAL KINGDOM

Phyla

I. PROTOZOA (prō'tō-zō'ȧ)—15,000 species. Single-celled animals. Reproduction by cell division.

Typical Classes

1. Rhizopods (rī'zō-pŏdz). Example: amoeba.
2. Sporozoa (spō-rō-zō'ȧ). Example: *Plasmodium malariae.*
3. Mastigophora (măs'tĭ-gŏf'ō-rȧ). Examples: Euglena, Noctiluca, Trypanosoma.
4. Ciliata (sĭl-ĭ-ā'tȧ). Examples: Paramecium, Stentor, Vorticella.

II. PORIFERA (pō-rĭf'ĕr-ȧ)—2,500 species. The sponges. Pores penetrate all parts of the body wall except the part attached to some substratum. The skeleton is composed of limy or glasslike spicules or horny material.

Typical Classes

1. Calcarea (kăl-kā'rē-ȧ). Shallow-water marine sponges. Example: Grantia.
2. Hexactinellida (hĕk-săk'tĭ-nĕl'ĭ-dȧ). Deep-sea sponges. Example: Venus's flower basket.
3. Demospongia (dē'mō-spŏn'jĭ-ȧ). Sea and fresh-water sponges, including all commercial sponges. Examples: cup sponges, horny sponges, bath sponges.

III. COELENTERATES (sē-lĕn′tẽr-āts)—10,000 species. Polyps, jellyfishes, and corals. Exist in both single forms and colonies. Individual bodies are usually baglike or cylindrical. The two common shapes are the polyp or hydroid form and the jellyfish or medusa form. Food is taken in and discharged through the same opening. Most coelenterates have tentacles for grasping food and bringing it into the mouth. Stinging cells are present on the tentacles and in some forms also in the body wall.

Typical Classes

1. HYDROZOA (hī′drō-zō′ȧ). Polyp forms are the most conspicuous. Examples: Hydra, Portuguese man-of-war, Obelia, Gonionemus (small jellyfish).
2. SCYPHOZOA (skī′fō-zō′ȧ). Medusa forms are the most conspicuous. Example: Aurelia (large jellyfish).
3. ANTHOZOA (ăn′thō-zō′ȧ). Polyp forms only. Examples: sea anemones, corals, sea pens, sea fans.

IV. PLATYHELMINTHES (plăt′ĭ-hĕl-mĭn′thēz)—5,000 species. Flatworms. Bodies flat, not segmented. Examples: Blanaria, liver fluke, tapeworm.

V. ROTIFERS (rō′tĭ-fẽrz)—700 species. Wheelworms.

VI. NEMATHELMINTHES (nĕm′ȧ-thĕl-mĭn′thēz)—50,000 species. Roundworms. Bodies cylindrical, not segmented, but possessing a body cavity. Examples: hookworm, vinegar eel, trichina.

VII. ANNELIDS (ăn′ĕ-lĭdz)—5,000 species. Worms with segmented bodies and body cavities. Example: earthworm.

VIII. ECHINODERMS (ē-kī′nō-dûrmz)—6,000 species. Radially symmetrical animals of the sea which have a limy exoskeleton and a water-vascular system. The exoskeleton consists of (1) plates that form a shell, (2) scattered particles or spines. Tube feet, when present, are used for locomotion.

Typical Classes

1. ASTEROIDEA (ăs-tẽr-oi′dē-ȧ). Body disk-shaped. Arms (usually five) radiate from central disk. Each one contains a tube foot. Example: starfish.
2. OPHIUROIDEA (ŏf′ĭ-ū-roi′dē-ȧ). Arms more slender and tube feet smaller than those of the Asteroidea. Example: brittle star.
3. ECHINOIDEA (ē-kī-noi′dē-ȧ). No true arms or rays. Body ball-like, hemispherical, or disk-shaped. Example: sea urchin.
4. HOLOTHUROIDEA (hŏl′ō-thū-roi′dē-ȧ). Body cucumber-shaped. Tentacles around mouth. Example: sea cucumber.

IX. MOLLUSKS (mŏl'ŭsks)—100,000 species. Soft-bodied animals which are usually protected by shell coverings. All have a muscular foot, a mantle, and a mantle cavity. Most forms are bilaterally symmetrical.

Typical Classes

1. GASTROPODA (găs-trŏp'ō-dȧ). Belly-footed mollusks. Examples: snails, slugs.
2. PELECYPODA (pê-lĕ-sĭp'ō-dȧ). Hatchet-footed mollusks. Examples: clams, oysters, mussels, scallops, shipworms.
3. CEPHALOPODA (sĕf'ȧ-lŏp'ō-dȧ). Head-footed mollusks. Examples: squid, octopus, cuttlefish.

X. ARTHROPODS (är'thrō-pŏdz)—more than 1,000,000 species. Animals with segmented bodies that have a chitinous exoskeleton and are bilaterally symmetrical. A part or all of the segments bear a pair of jointed appendages.

Typical Classes

Gill-breathing animals that live in water

1. CRUSTACEANS (krŭs-tā'shăns). Crusty-shelled animals. Examples: crayfish, lobster, cyclops.

Air-breathing animals

2. MYRIAPODS (mĭr'ĭ-ȧ-pŏdz'). Many-legged animals. Examples: centipedes, millepedes.
3. ARACHNIDS (ȧ-răk'nĭdz). Eight-legged animals. Examples: spider, scorpion, termite, mite.
4. HEXAPODS (hĕk'sȧ-pŏdz)—500,000 to 1,000,000 species. The insects. Six-legged animals. Their bodies are divided into head, thorax, and abdomen. The legs are attached to the thorax. Adults usually have two or four wings.

Typical Orders

a. Thysanura (thī-sȧ-nū'rȧ). No metamorphosis. Biting mouth parts. No wings. Examples: springtail, fish moth, snow flea.
b. Odonata (ō-dō-nā'tȧ). Incomplete metamorphosis. Biting mouth parts. Membranous netted wings. Example: dragon fly.
c. Isoptera (ī-sŏp'tẽr-ȧ). Incomplete metamorphosis. Biting mouth parts. Leathery wings. Example: termite.
d. Orthoptera (ôr-thŏp'tẽr-ȧ). Incomplete metamorphosis. Biting mouth parts. Thick front wings, thin hind wings. Examples: grasshopper, walking stick, katydid, cockroach, locust.
e. Hemiptera (hê-mĭp'tẽr-ȧ). Incomplete metamorphosis. Piercing and sucking mouth parts. When wings are present, front pair folds over back of the body. Examples: all true bugs, such as bedbug, water boatman, giant water bug, water strider, squash bug.

f. Homoptera (hō-mŏp′tẽr-*ȧ*). Incomplete metamorphosis. Piercing and sucking mouth parts. Usually four wings. Examples: aphid, cicada, scale insects, leaf hoppers.

g. Neuroptera (nū-rŏp′tẽr-*ȧ*). Complete metamorphosis. Biting mouth parts. Wings with many veins. Examples: ant lion, dobson fly.

h. Lepidoptera (lĕp′ĭ-dŏp′tẽr-*ȧ*). Complete metamorphosis. Piercing and sucking mouth parts. Wings covered with scales. Examples: butterfly, moth.

i. Diptera (dĭp′tẽr-*ȧ*). Complete metamorphosis. Piercing and sucking mouth parts. Two wings. Examples: fly, mosquito.

j. Siphonaptera (sī′fō-năp′tẽr-*ȧ*). Complete metamorphosis. Piercing and sucking mouth parts. No wings. Examples: dog flea, cat flea, human flea, chigger.

k. Coleoptera (kō′lē-ŏp′tẽr-*ȧ*). Complete metamorphosis. Biting mouth parts. Shell-like front wings, membranous hind wings. Examples: beetle, weevil, firefly.

l. Hymenoptera (hī′mĕn-ŏp′tẽr-*ȧ*). Complete metamorphosis. Biting and sucking mouth parts. Wings with few veins. Examples: bee, wasp, ant, ichneumon fly, gall fly.

XI. CHORDATES (kôr′dāts)—63,500 species. During some stage in their development these animals have (1) an axial skeleton called the notochord, which is composed of elastic tissue, (2) gill slits in the walls of the pharynx, and (3) a dorsal central nervous system. There are four subphyla, only one of which is given here.

Important Subphylum

A. VERTEBRATES (vẽr′tē-brāts). Notochord present at some time during the life history of an individual. In the adult stage of higher vertebrates the notochord disappears and is replaced by a spinal column made up of bones called vertebrae.

Typical Classes

1. PISCES (pĭs′ēz). Fishes. Cold-blooded animals that live in water. Most forms breathe by means of gills. Limbs are developed as fins.

Typical Orders

a. Elasmobranchs (ē-lăs′mō-brăŋkz). Cartilaginous fishes. Examples: shark, skate, sawfish.

b. Ganoids (găn′oidz). Armored fishes. Examples: sturgeon, paddlefish, gar pike.

c. Teleostans (tĕl′ē-ŏs′tȧnz). Bony fishes. Examples: perch, bass, salmon, trout, catfish, swordfish, sea horse, shad, cod, mackerel, sunfish, goldfish.

d. Dipnoans (dĭp′nō-ȧnz). Lungfishes. Examples: Australian, African, and South American lungfishes.

2. AMPHIBIANS (ăm-fĭb′ĭ-ȧnz)—1,500 species. Cold-blooded animals that live in water or damp places. The larvae are called tadpoles or polliwogs and breathe by means of gills. Lungs take the place of gills in the adult.

Typical Orders

a. Urodela (ū-rō-dē′lȧ). Tailed amphibians. Examples: salamander, newt.

b. Anura (ȧ-nū′rȧ). Tailless amphibians. Examples: toad, frog.

3. REPTILES (rĕp′tĭlz)—6,500 species. Cold-blooded, lung-breathing animals that have a cover of scales or horny plates.

Typical Orders

a. Chelonia (kē-lō′nĭ-ȧ). Examples: turtles, tortoises.

b. Serpentes (sẽr-pĕn′tēz). Examples: king snake, rattlesnake, water moccasin.

c. Lacertilia (lăs′ẽr-tĭl′ĭ-ȧ). Examples: frilled lizard, chameleon, Gila monster.

d. Crocodilia (krŏk′ō-dĭl′ĭ-ȧ). Examples: crocodile, alligator.

4. AVES (ā′vēz)—20,000 species. Birds. Distinguished from all other animals by their feathers. Warm-blooded and toothless. Aided in flying by some hollow bones and by air spaces in their bodies.

Typical Orders

a. Anseriformes (ăn′sẽr-ĭ-fôr′mēz). Gooselike birds. Examples: duck, goose, swan.

b. Galliformes (găl′ĭ-fôr′mēz). Fowl-like birds. Examples: chicken, turkey, sage hen, quail, grouse.

c. Charadriiformes (kȧ-răd′rĭ-ĭ-fôr′mēz). Shore birds. Examples: penguin, plover, gull, sandpiper.

d. Passeriformes (păs′ẽr-ĭ-fôr′mēz). Perching birds. Most of the songbirds and more than half of all known species belong to the order. Examples: robin, cardinal, blue jay, crow, wren, sparrow, whip-poor-will, shrike, warbler, blackbird.

e. Coraciiformes (kôr′ȧ-sĭ′ĭ-fôr′mēz). Roller-like birds. Examples: woodpecker, owl, kingfisher, flicker, hummingbird.

f. Falconiformes (făl'kŏ-nĭ-fôr'mēz). Birds of prey. Examples: eagle, vulture, buzzard, hawk.

5. MAMMALS (măm'ălz)—20,000 species. Warm-blooded animals. All forms have an epidermis more or less covered with hair. The female has glands for nourishing her young with milk.

Typical Orders

Egg-laying mammals

a. Monotremata (mŏn'ŏ-trē'mȧ-tȧ). Egg-laying mammals. Examples: duckbill, echidna.

Viviparous mammals

b. Marsupialia (mär-sū'pĭ-ā'lĭ-ȧ). Pouched animals. Examples: opossum, kangaroo.

c. Chiroptera (kī-rŏp'tẽr-ȧ). Winged mammals. Example: bat.

d. Insectivora (ĭn'sĕk-tĭv'ŏ-rȧ). Insect-eating mammals. Examples: mole, shrew.

e. Edentata (ē'dĕn-tā'tȧ). Toothless mammals. Examples: sloth, great anteater, armadillo.

f. Rodentia (rŏ-dĕn'shĭ-ȧ). Gnawing mammals. Examples: rabbit, beaver, mouse, muskrat, porcupine, squirrel.

g. Carnivora (kär-nĭv'ŏ-rȧ). Flesh-eating mammals. Examples: dog, cat, lion, bear, coyote, fox, seal, raccoon, skunk.

h. Ungulata (ŭn'gū-lā'tȧ). Hoofed mammals. Examples: *odd-toed*—horse, rhinoceros; *even-toed*—deer, cow, pig, sheep, giraffe, bison.

i. Proboscidea (prō'bŏ-sĭd'ē-ȧ). Example: elephant.

j. Cetacea (sē-tā'shē-ȧ). Fishlike mammals. Examples: whale, dolphin, porpoise.

k. Primates (prī-mā'tēz). Erect mammals. Examples: man, gorilla.

Typical Families

(1) Hominidae (hŏ-mĭn'ĭ-dē). Human race.

Genus

(*a*) Homo (hō'mō).

Species

1. Sapiens (sā'pĭ-ĕnz).

Varieties

a) Caucasian (white).

b) Mongolian (yellow).[1]

c) Negro (black).

[1] Includes American Indian (red) and Malayan (brown).

BIBLIOGRAPHY

AREY, LESLIE BRAINERD. *Developmental Anatomy.* W. B. Saunders Co., Philadelphia. 1930.

BARNES, H. E. *The Story of Punishment.* Stratford Co., Boston. 1930.

BARROWS, WILLIAM M. *Science of Animal Life.* World Book Co., Yonkers-on-Hudson, New York. 1927.

BEAN, ROBERT BENNETT. *The Races of Man.* The University Society, Inc., New York. 1935.

BEARD, DANIEL C. *American Boys' Book of Bugs, Butterflies and Beetles.* J. B. Lippincott Co., Philadelphia. 1915.

BEEBE, CHARLES WILLIAM. *Half-Mile Down.* Harcourt, Brace & Co., New York. 1934.

BEEBE, CHARLES WILLIAM. *Jungle Days.* G. P. Putnam's Sons, New York. 1925.

Book of Knowledge, The. The Grolier Society, New York. 1930.

Book of Popular Science, The. The Grolier Society, New York. 1930.

BRANSON, E. B., and TARR, W. A. *Introduction to Geology.* McGraw-Hill Book Co., New York. 1935.

BROWN, R. N. RUDMOSE. *The Polar Regions.* Methuen & Co., London. 1927.

BUCK, FRANK. *Fang and Claw.* Simon & Schuster, New York. 1935.

BULL, RAYMOND C., and THOMAS, STANLEY J. *Freshman Hygiene.* J. B. Lippincott Co., Philadelphia. 1926.

BYRD, RICHARD E. *Little America.* G. P. Putnam's Sons, New York. 1930.

CALKINS, GARY N. *The Smallest Living Things.* The University Society, Inc., New York. 1932.

CARPENTER, GEORGE H. *Biology of Insects.* The Macmillan Co., New York. 1928.

CARPENTER, GEORGE H. *Insects: Their Structure and Life.* E. P. Dutton & Co., New York. 1924.

CHAPMAN, FRANK M. *Bird Life.* D. Appleton-Century Co., New York. 1930.

CLARK, AUSTIN H. *Animals of Land and Sea.* D. Van Nostrand & Co., New York. 1925.

CLARK, AUSTIN H. *Nature Narratives.* Williams & Wilkins Co., Baltimore. 1929.

Compton's Pictured Encyclopedia. F. E. Compton Co., Chicago. 1937.

COMSTOCK, JOHN HENRY. *Insect Life.* D. Appleton-Century Co., New York. 1925.

COULTER, JOHN M.; BARNES, CHARLES R.; and COWLES, HENRY C. *A Textbook of Botany.* (3 volumes.) American Book Co., New York. 1930.

Cramp, Arthur J. *Nostrums and Quackery* (Vol. 1, 1911; Vol. 2, 1921). American Medical Association, 535 N. Dearborn St., Chicago.

Crowder, William. *A Naturalist at the Seashore.* D. Appleton-Century Co., New York. 1928.

Davenport, Charles B. *How We Came by Our Bodies.* Henry Holt & Co., New York. 1936.

De Kruif, Paul. *Microbe Hunters.* Harcourt, Brace & Co., New York. 1926.

Diehl, Harold S. *Healthful Living.* Whittlesey House, New York. 1935.

Ditmars, Raymond L. *Reptiles of the World.* The Macmillan Co., New York. 1927.

Downing, Elliott R. *Elementary Eugenics.* The University of Chicago Press, Chicago. 1928.

Drew, A. H., and Wright, Lewis. *The Microscope.* Religious Tract Society, London. 1929.

Eifrig, C. W. G. *Our Great Outdoors: Reptiles, Amphibians, and Fishes.* Rand McNally & Company, Chicago. 1930.

Ellwood, Charles A. *Sociology and Modern Social Problems.* American Book Co., New York. 1924.

Encyclopedia Americana. American Corporation, Chicago. 1932.

Encyclopaedia Britannica. 14th Edition. Encyclopaedia Britannica, Inc., New York. 1929–1930.

Fish, Helen Dean. Collector of *The Boys' Book of Verse.* Frederick A. Stokes Company, New York. 1923.

Fishbein, Morris. *The New Medical Follies.* Boni & Liveright, Inc., New York. 1927.

Flower Gardening. Short Stories from the Farm and Garden Department, *Chicago Tribune.* 1930.

Galloway, Thomas Walton. *Reproduction.* John G. Coulter, School Science Series, Bloomington, Ill. 1916.

Grey, Zane. *Book of Camps and Trails.* Harper Brothers, New York. 1931.

Guttmacher, Alan Frank. *Life in the Making.* The Viking Press, New York. 1933.

Haggard, Howard W. *Mystery, Magic, and Medicine.* Doubleday, Doran & Co., Inc., Garden City, New York. 1933.

Hardy, M. E. *Geography of Plants.* Oxford University Press. 1925.

Hill, A. V. *Living Machinery.* Harcourt, Brace & Co., New York. 1927.

Hoffman, Dr. Richard H. *The Struggle for Health.* Liveright, New York. 1929.

Hornaday, William T. *The Minds and Manners of Wild Animals.* Charles Scribner's Sons, New York. 1922.

Hough, Theodore; Sedgwick, William T.; and Waddell, J. A. *The Human Mechanism.* Ginn & Co., Boston. 1929.

HUNTINGTON, ELLSWORTH. *Tomorrow's Children: The Goal of Eugenics.* John Wiley & Sons, New York. 1935.

JEWETT, FRANCES GULICK. *The Next Generation.* Ginn & Co., Boston. 1914.

KELLOGG, VERNON L. *Evolution.* D. Appleton-Century Co., New York. 1924.

KEPHART, HORACE. *Camping and Woodcraft.* The Macmillan Co., New York. 1930.

KINBERG-VON SNEIDERN, JULIA, and SUNDQUIST, ALMA. *Sex Hygiene.* Henry Holt & Co., New York. 1926.

KNIGHT, JOHN ALDEN. *The Modern Angler.* Charles Scribner's Sons, New York. 1936.

KOPELOFF, NICHOLAS. *Man versus Microbes.* Alfred A. Knopf, New York. 1930.

KOVACS, RICHARD. *Nature, M. D.* D. Appleton-Century Co., New York. 1934.

LYNCH, V. E. *Trails to Successful Trapping.* A. R. Harding Publishing Co., Columbus, Ohio. 1935.

MAETERLINCK, MAURICE. *The Life of the Bee.* Dodd, Mead & Co., New York. 1913.

MANN, PAUL B., and HASTINGS, GEORGE T. *Out of Doors.* Henry Holt & Co., New York. 1932.

MATHENY, WILLIAM A. *Seed Dispersal.* Slingerland-Comstock Co., Ithaca, New York. 1931.

MATHER, KIRTLEY F. *Sons of the Earth.* W. W. Norton & Co., New York. 1930.

MATHEWS, F. SCHUYLER. *The Book of Wild Flowers for Young People.* G. P. Putnam's Sons, New York. 1923.

MATHEWS, F. SCHUYLER. *Familiar Trees and Their Leaves.* D. Appleton-Century Co., New York. 1911.

METCALF, C. L., and FLINT, W. P. *Fundamentals of Insect Life.* McGraw-Hill Book Co., Inc., New York. 1932.

Nature Magazine. American Nature Association, 1214 Sixteenth St., N. W., Washington, D. C.

NEEDHAM, JAMES GEORGE. *The Animal World.* University Society, New York. 1931.

New International Encyclopedia, The. Dodd, Mead & Co., New York. 1924.

New Wonder World, The. Geo. L. Shuman & Co., Chicago. 1936.

NEWBIGIN, MARION I. *Animal Geography.* Oxford University Press. 1913.

O'TOOLE, GEORGE BARRY. *The Case against Evolution.* The Macmillan Co., New York. 1925.

PACK, CHARLES L. *The Forestry Primer.* American Tree Association, Washington, D. C. 1926.

PARK, WILLIAM H., and WILLIAMS, ANNA W. *Who's Who among the Microbes.* D. Appleton-Century Co., New York. 1929.

PARSHLEY, H. M. *Science of Human Reproduction.* W. W. Norton Co., Inc., New York. 1933.

PARSONS, FRANCES THEODORA DANA. *How to Know the Wild Flowers.* Charles Scribner's Sons, New York. 1900.

PICKWELL, GAYLE, Editor. *Insects.* Western Nature Series Study. Williams Publishing Co., San Francisco. 1935.

RICE, THURMAN B. *The Conquest of Disease.* The Macmillan Co., New York. 1927.

RICE, THURMAN B. *Racial Hygiene.* The Macmillan Co., New York. 1929.

ROBBINS, WILFRED W. *Sex in the Plant World.* D. Appleton-Century Co., New York.

ROBBINS, WILFRED W., and ISENBARGER, JEROME. *Practical Problems in Botany.* John Wiley & Sons, New York. 1936.

ROGERS, JULIA ELLEN. *Trees Worth Knowing.* Doubleday, Doran & Co., New York. 1916.

ROLFE, R. T., and ROLFE, F. W. *Romance of the Fungus World.* J. B. Lippincott, Philadelphia. 1926.

ROSS, EDWARD. *The Outline of Sociology.* D. Appleton-Century Co., New York. 1923.

SCHMUCKER, SAMUEL. *Heredity and Parenthood.* The Macmillan Co., New York. 1929.

SETON, ERNEST THOMPSON. *Lives of Game Animals.* Doubleday, Doran & Co., New York. 1925–1928.

SETON, ERNEST THOMPSON. *Lives of the Hunted.* Charles Scribner's Sons, New York. 1901.

SHIPLEY, SIR ARTHUR E. *Life.* The Macmillan Co., New York. 1923.

SIPLE, PAUL. *A Boy Scout with Byrd.* G. P. Putnam's Sons, New York. 1931.

SOLOMON, BEN. *Hiker's Guide.* Leisure League of America, New York. 1934.

STEVENS, G. A. *Garden Flowers in Color.* The Macmillan Co., New York. 1934.

STOPES, MARIE C. *The Human Body and Its Functions.* G. P. Putnam's Sons, New York. 1926.

STOWELL, WILLIAM LELAND. *Sex for Parents and Teachers.* The Macmillan Co., New York. 1921.

STRAIN, FRANCES BRUCE. *Being Born.* D. Appleton-Century Co., New York. 1936.

TARR, RALPH S., and VON ENGELN, O. D. *New Physical Geography.* The Macmillan Co., New York. 1926.

THOMSON, J. ARTHUR. *Biology for Everyman.* E. P. Dutton & Co., Inc., New York. 1935.

THOMSON, SIR J. ARTHUR. *Riddles of Science.* Liveright, Inc., New York. 1932.

TOBEY, JAMES A. *Riders of the Plagues.* Charles Scribner's Sons, New York. 1930.

TOSE, FRANK. *Trapping, Tanning, and Taxidermy.* Hunter, Trader, and Trapper Magazine Co., Columbus, Ohio. 1928.

TRANSEAU, EDGAR NELSON. *General Botany.* World Book Co., Yonkers-on-Hudson, New York. 1923.

TRANSEAU, EDGAR NELSON. *Science of Plant Life.* World Book Co., Yonkers-on-Hudson, New York. 1919.

WADDINGTON, C. H. *How Animals Develop.* George Allen & Unwin Ltd., London. 1935.

WARD, FRANCIS KINGDON. *Romance of Plant Hunting.* Edward Arnold & Co., London. (Longmans, Green & Co., New York.) 1924.

WARD, HENRY B., and WHIPPLE, GEORGE C. *Manual of Fresh-Water Biology.* John Wiley & Sons, Inc., New York. 1918.

WASHBURN, MARGARET. *The Animal Mind.* The Macmillan Co., New York. 1936.

WELLHOUSE, WALTER HOUSLEY. *How Insects Live.* The Macmillan Co., New York. 1928.

WERTHNER, WILLIAM B. *Some American Trees.* The Macmillan Co., New York. 1935.

WHEELER, WILLIAM M. *Social Life among the Insects.* Harcourt, Brace & Co., New York. 1923.

WHITNALL, HAROLD O. *A Parade of Ancient Animals.* Thomas Y. Crowell, New York. 1936.

WIGGAM, ALBERT EDWARD. *The Fruit of the Family Tree.* The Bobbs-Merrill Co., Indianapolis, Ind. 1924.

WILLIAMS, HENRY SMITH. *Drugs against Men.* Robert M. McBride & Co., New York. 1935.

WILLIAMS, JESSE FEIRING. *Healthful Living.* The Macmillan Co., New York. 1931.

World Book Encyclopedia, The. W. F. Quarrie & Co., Chicago. 1936.

YATES, RAYMOND F. *Exploring with the Microscope.* D. Appleton-Century Co., New York. 1934.

ZINNSSER, HANS. *Rats, Lice, and History.* Atlantic Monthly Press and Little, Brown & Co., Boston. 1935.

GLOSSARY

KEY TO PRONUNCIATION

ā as in *a*te	ē as in p*e*t	ū as in *u*se
ȧ as in sen*a*te	ĕ as in abs*e*nt	û as in *u*nite
ă as in c*a*t	ẽ as in lov*e*r	û as in t*u*rn
ă as in *a*ccount	ī as in k*i*nd	ŭ as in *u*p
ä as in *a*rm	ĭ as in *i*t	ŭ as in circ*u*s
ȧ as in *a*sk	ĭ as in char*i*ty	o͞o as in f*oo*d
a as in sof*a*	ō as in *o*ld	o͝o as in f*oo*t
ē as in *e*ve	ō as in *o*bey	oi as in *oi*l
ê as in *e*vent	ô as in *o*r	ŋ as in i*n*k
ḛ as in h*e*re	ŏ as in h*o*t	zh = a*z*ure
	ŏ as in c*o*nnect	

Abdomen (ăb-dō′mĕn): the cavity in the body that contains the liver, stomach, spleen, intestines, pancreas, and kidneys; in insects, the region behind the thorax.

Absorption (ăb-sôrp′shŭn): the taking in of fluids by living cells or tissues.

Acidosis (ăs′ĭ-dō′sĭs): a condition of the blood that comes from the excessive burning or oxidizing of acid-forming foods.

Adaptation (ăd′ăp-tā′shŭn): a modification in plants or animals that enables them to live in harmony with their environment.

Adenoids (ăd′ē-noidz): swollen tissues in the roof of the pharynx that interfere with the passage of air.

Adrenals (ăd-rē′năl z): ductless glands attached to the kidneys which activate the nervous system through the secretion of hormones.

Aërobic bacteria (ā′ẽr-ō′bĭk băk-tḛr′ĭ-*a*): organisms that need free oxygen in order to exist.

Afferent neurons (ăf′ẽr-ĕnt nū′-rŏnz): those that receive impressions from end organs and transmit them to the spinal cord and brain; same as *sensory neurons.*

Agglutinin (*a*-glo͝o′tĭ-nĭn): an antibody that causes germs and red corpuscles to stick together in clumps, thus making it easier for the phagocytes to catch and engulf the germs.

Albumen (ăl-bū′mĕn): the white of egg.

Albumin (ăl-bū′mĭn): a proteid found in the serum of the blood, in other animal substances, and in certain plant tissues and liquids.

Alga (ăl′g*a*): a simple plant belonging to the phylum of thallophytes.

Allantois (ă-lăn′tō-ĭs): an organ in the embryo of a reptile, bird, or mammal, that serves as a respiratory tract, enabling it to secure oxygen and release carbon dioxide.

Alveoli (ăl-vē′ō-lī): the pouchlike sacs of the lungs.

Amino (ă-mē′nō) **acid:** the chief food product obtained from the digestion of proteins.

Amitosis (ăm′ĭ-tō′sĭs): direct cell division, in which there is a simple cleavage of the nucleus without change in structure, followed by a division of the cytoplasm.

Amnion (ăm′nĭ-ŏn): a thin membrane that forms a closed sac around the embryo of reptiles, birds, and mammals.

Amphibian (ăm-fĭb′ĭ-ăn): an animal that lives part of the time on land and part of the time in water, such as a frog or a salamander.

Amylopsin (ăm′ĭ-lŏp′sĭn): an enzyme in the pancreatic juice that changes starch to sugar.

Anaërobic (ăn-ā′ẽr-ō′bĭk) **bacteria** (băk-tḛr′ĭ-*a*): organisms that do

not require free oxygen in order to exist.

Anatomy (*ȧ*-năt′ō-mĭ): the study of the structure of organisms.

Anesthetic (ăn′ĕs-thĕt′ĭk): a substance that brings about a partial or complete loss of feeling.

Angiosperms (ăn′jĭ-ō-spûrmz): plants that bear flowers and have seeds inclosed in ovaries; a subphylum of spermatophytes.

Annelids (ăn′ĕ-lĭdz): a phylum of segmented worms including the earthworm.

Annuals (ăn′ū-*ă*lz): plants that live but one year.

Anopheles (*ȧ*-nŏf′*ĕ*-lēz): the kind of mosquito that carries the germs of malaria.

Antennae (ăn-tĕn′ē): movable, jointed appendages on the heads of insects, myriapods, and crustaceans that serve as sense organs.

Anterior (ăn-tēr′ĭ-ēr) **end:** head or front end of the body of an animal.

Anther (ăn′thēr): the part of a stamen that bears pollen.

Antheridium (ăn′thēr-ĭd′ĭ-*ŭ*m): male organ in the sexual generation of such plants as ferns and mosses.

Anthrax (ăn′thrăks): an infectious bacterial disease that attacks cattle and sheep and sometimes man.

Antibody (ăn′tĭ-bŏd′ĭ): a substance in the blood that combats harmful toxins or bacteria.

Antiseptic (ăn′tĭ-sĕp′tĭk): a substance that retards or prevents the growth of disease-producing bacteria.

Antitoxin (ăn′tĭ-tŏk′sĭn): a serum the antibodies of which neutralize the toxins given off by disease-producing bacteria.

Anus (ā′n*ŭ*s): the excretory opening of the digestive tract.

Aorta (ā-ôr′t*ȧ*): the large artery that arises at the left ventricle of the heart and carries pure blood to all parts of the body except the lungs.

Aphid (ā′fĭd): a plant louse that sucks the juices of plants and serves as a cow for ants.

Appendage (ă-pĕn′dĭj): the limb of an animal.

Aquarium (*ȧ*-kwâr′ĭ-*ŭ*m): a glass tank used as a miniature habitat for aquatic plants and animals.

Aquatic (*ȧ*-kwăt′ĭk): living in water.

Arachnids (*ȧ*-răk′nĭdz): a class of eight-legged arthropods including spiders and scorpions.

Archegonium (är′kē-gō′nĭ-*ŭ*m): the egg-producing organ of the bryophytes, pteridophytes, and gymnosperms.

Artery (är′tēr-ĭ): a vessel that carries pure blood away from the heart.

Arthropods (är′thrō-pŏdz): a phylum of animals, including insects, spiders, and crayfish, that have segmented bodies, jointed appendages, and chitinous exoskeletons.

Asexual (*ȧ*-sĕk′shū-*ă*l) **reproduction:** reproduction by amitosis, mitosis, the formation of spores, and other types not involving sex.

Assimilation (*ă*-sĭm′*ĭ*-lā′sh*ŭ*n): the process by which the cells take up digested food for conversion into protoplasm.

Atom (ăt′*ŭ*m): the smallest particle of an element that can unite with another particle to form a molecule.

Auditory (ô′dĭ-tō′rĭ) **nerve:** the nerve that carries sound stimuli from the ear to the brain.

Auricle (ô′rĭ-k′l): one of the chambers of the heart that receives the blood from the veins.

Autonomic (ô′tō-nŏm′ĭk) **nervous system:** the part of the nervous system that controls involuntary movements: sometimes called the *sympathetic nervous system.*

Axon (ăk′sŏn): the long threadlike portion of a nerve cell.

Bacillus (b*ȧ*-sĭl′*ŭ*s; plural, **bacilli,** b*ȧ*-sĭl′ĭ): a genus of rod-shaped bacteria.

Bacterium (băk-tēr′ĭ-*ŭ*m): a microscopic one-celled plant that lacks chlorophyll.

Bacteriology (băk-tēr′ĭ-ŏl′ō-jĭ): the study of bacteria.

Bacteriophage (băk-tēr′ĭ-ō-fāj): a tiny body too small to be seen

through the microscope, destructive to disease-producing bacteria.

Bark (bärk): the outer layers of woody stems, including the phloem and cortex and, in young plants, the epidermis.

Bathysphere (băth'ĭ-sfēr): a steel ball, 4½ feet in diameter, 1½ feet thick, and with visual portholes, in which Charles William Beebe has made explorations and taken photographs at different sea depths.

Behavior: the manner in which an organism acts or responds.

Beriberi (bĕr'ĭ-bĕr'ĭ): a disease of the nerves accompanied by loss of appetite, poor digestion, and paralysis.

Bile (bīl): a fluid secreted by the liver and used in the small intestine to aid in digestion and to prevent putrefaction.

Biology (bī-ŏl'ō-jĭ): the science of life, including a study of the development, structure, and behavior of living organisms.

Bisexual (bī-sĕk'shū-ăl): having both male and female sex organs in the same individual.

Bivalves (bī'vălvz): two parts of a mollusk shell joined at one side by a ligament that serves as a hinge.

Blastula (blăs'tū-lȧ): a stage in the development of an animal embryo in which the cells are arranged in a single layer, with a cavity in the center somewhat like a hollow sphere.

Botany (bŏt'ȧ-nĭ): the science of plants, involving a study of development, structure, and behavior.

Bronchi (brŏn'kī): the two branches of the windpipe that lead to the lungs.

Bryophytes (brī'ō-fīts): the phylum of plants that includes the liverworts and mosses.

Bud (bŭd): a compact group of leaves or flowers or both at the end of a growing stem.

Bulb (bŭlb): a cluster of food-storing, overlapping leaves or leaf bases arising from an inconspicuous stem.

Calorie (kăl'ō-rĭ): the amount of heat required to raise the temperature of 1 kilogram of water 1° Centigrade.

Calyx (kā'lĭks): all of the sepals of a flower.

Cambium (kăm'bĭ-ŭm) **layer**: the layer of cells between the phloem and xylem in a woody stem or root.

Capillaries (kăp'ĭ-lā-rĭz): small tubes that connect the branches of the arteries with those of the veins.

Carbohydrate (kär'bō-hī'drāt): a class of foods including starches and sugars composed of carbon, hydrogen, and oxygen.

Carbon (kär'bŏn): a chemical element found in organic matter.

Carbon dioxide (dī-ŏk'sīd): a gaseous compound consisting of carbon and oxygen used by plants in the manufacture of food.

Cardiac (kär'dĭ-ăk): pertaining to the heart or upper end of the stomach.

Carnivora (kär-nĭv'ō-rȧ): an order of flesh-eating mammals including cats and dogs.

Cartilage (kär'tĭ-lĭj): a tough, elastic tissue in animals, sometimes called gristle.

Cell (sĕl): a unit of organic structure, consisting of a mass of protoplasm and a nucleus.

Cell differentiation (dĭf'ēr-ĕn'shĭ-ā'shŭn): the variation in the nature of cells which enables them to perform different functions.

Cellulose (sĕl'ū-lōs): the substance that makes up the greater part of the walls of a plant cell.

Centipede (sĕn'tĭ-pēd): a small arthropod with many legs and conspicuous antennae.

Centrosome (sĕn'trō-sōm): a minute protoplasmic body within the centrosphere which plays an important part in mitosis.

Centrosphere (sĕn'trō-sfēr): a small body near the nucleus of an animal cell which contains the centrosome.

Cephalopoda (sĕf'ȧ-lŏp'ō-dȧ): a class of mollusks represented by squids and octopuses.

Cerebellum (sĕr′ĕ-bel′ŭm): the part of the brain that lies between the cerebrum and medulla oblongata.

Cerebrum (sĕr′ĕ-brŭm): the large upper part of the brain.

Cetacea (sė-tā′shė-ȧ): an order of aquatic mammals with fishlike bodies, fore limbs modified for swimming, and no hind limbs.

Chalazae (kȧ-lā′zē): twisted cords of albumen that keep the yolk of an egg in place.

Character (kăr′ăk-tẽr): a trait or characteristic of a plant or animal, such as color, height, or shape.

Chemotropism (kĕ-mŏt′rō-pĭz′m): the reaction of plants or animals to chemicals in solution.

Chitin (kī′tĭn): a horny material in the exoskeleton of insects and crustaceans.

Chlorophyll (klō′rō-fĭl): a green coloring matter in plant cells necessary for food making.

Chloroplasts (klō′rō-plăsts): small bodies in plant cells that contain the chlorophyll.

Chordates (kôr′dāts): a phylum of animals that have a notochord or a backbone.

Chorion (kō′rĭ-ŏn): the membrane that envelops the young of mammals before birth, surrounding the amnion.

Choroid (kō′roid): the middle coat of the eye.

Chromatin (krō′mȧ-tĭn): a protoplasmic granule in the nucelus of cells that breaks up into chromosomes prior to cell division.

Chromosomes (krō′mō-sōmz): the structures in the nucleus of a cell that bear the genes or unit characters of heredity.

Chrysalis (krĭs′ȧ-lĭs): the inactive or pupa stage in the metamorphosis of insects.

Chyme (kīm): food liquefied by the action of the stomach.

Cilia (sĭl′ĭ-ȧ): vibrating hairlike projections on cells.

Circulation (sûr-kū-lā′shŭn): the movement of blood through the body of an animal or the movement of sap in a plant.

Cleavage (klēv′ĭj): early stages of cell division in a fertilized animal egg.

Clinic (klĭn′ĭk): an institution for the diagnosis and treatment of disease.

Cloaca (klō-ā′kȧ): a cavity in the bodies of birds, reptiles, amphibians, and certain fishes that serves as a receptacle for discharges from the intestinal, urinary, and genital tracts.

Coccus (kŏk′ŭs; plural, **cocci,** kŏk′sī): a bacterium with spherical form.

Cochlea (kŏk′lė-ȧ): a spiral-shaped tube in the inner ear which transmits the vibrations of sound to the auditory nerve.

Cochineal (kŏch′ĭ-nēl′) **insects:** small lice that live on cactus plants in Mexico.

Coelenterates (sė-lĕn′tẽr-āts): a phylum of animals that includes the sea anemone and coral.

Complete metamorphosis (mĕt′ȧ-môr′fō-sĭs): the four stages in the development of an insect—egg, larva, pupa, adult.

Conifer (kō′nĭ-fẽr): a cone-bearing tree.

Conjugation (kŏn′jōō-gā′shŭn): the union of two like gametes, corresponding to fertilization in higher forms of life.

Convolutions (kŏn′vō-lū′shŭnz): irregular folds of gray matter on the outer surface of the cerebrum.

Cornea (kôr′nė-ȧ): the transparent membrane that protects the iris and pupil at the front of the eye.

Corolla (kō-rŏl′ȧ): all the petals of a flower.

Cotyledon (kŏt′ĭ-lē′dŭn): the first leaf or one of the first pair or whorls of leaves developed by a plant embryo.

Cranium (krā′nĭ-ŭm): the skull or bony shell which incloses the brain.

Creosote (krē′ō-sōt): an oily liquid antiseptic and preservative distilled from wood.

Cross-pollination: the transfer of pollen from the anther of one flower to the stigma of another.

Crustaceans (krŭs-tā'shŭnz): a class of arthropods that live in water and breathe by means of gills, as the crayfish and the lobster.
Culex (kū'lěks): the common mosquito—annoying but harmless.
Culture media (mē'dĭ-*ȧ*): food prepared for the growing of microscopic forms of life, such as bacteria, yeasts, and Protozoa.
Cyanide (sī'*ȧ*-nīd): a deadly poison.
Cytoplasm (sī'tō-plăz'm): the protoplasm in a cell outside the nucleus.

Deciduous (dē-sĭd'ū-*ŭ*s): having leaves that are shed in the fall.
Dendrites (děn'drīts): the sensitive treelike branches around a nerve cell.
Deodorant (dē-ō'dẽr-*ă*nt): any substance that destroys or masks an offensive odor.
Dermis (dûr'mĭs): the layer of skin beneath the epidermis that contains blood vessels and nerves.
Diaphragm (dī'*ȧ*-frăm): an elastic muscular membrane that separates the chest from the abdomen.
Diastase (dī'*ȧ*-stās): an enzyme that changes starches to sugar (glucose).
Diaster (dī-ăs'tẽr) **stage**: the stage in the mitosis of a plant cell in which the fibers attached to the chromosomes shorten, the chromosomes split lengthwise into equal parts, and the two halves are drawn toward the opposite poles.
Diatoms (dī'*ȧ*-tŏmz): one-celled microscopic plants belonging to the algae family.
Dick test: a test to determine whether a person is immune to scarlet fever.
Dicotyledon (dī-kŏt'ĭ-lē'd*ŭ*n): a seed-bearing plant in which the embryo has two cotyledons.
Diffusion (dĭ-fū'sh*ŭ*n): a process of even distribution that takes place between two or more substances, such as liquids.
Digestion (dĭ-jĕs'ch*ŭ*n): sum total of the processes by which foods are converted into usable form.
Dihybrid (dī-hī'brĭd): the offspring that results from the mating of individuals differing in two unit characters.
Dinosaurs (dī'nō-sôrz): an order of extinct reptiles, many of them of gigantic size.
Diphtheria (dĭf-thẹr-ĭ-*ȧ*): a bacterial disease that attacks the membranes of the throat.
Disease (dĭ-zēz'): a disturbance in any part of the body.
Disinfection (dĭs'ĭn-fěk'sh*ŭ*n): the act or process of destroying disease germs.
Dispirem (dī-spī'rēm) **stage**: the stage in the mitosis of a plant cell in which (1) the daughter chromosomes at the two poles of the spindle unite to form a spirem, and a nuclear membrane surrounds each group; and (2) the spindle fibers thicken at the midpoint, forming the cell plate.
Dominant character: the characteristic that appears in a hybrid, such as tallness or shortness.
Dorsal (dôr's*ă*l) **surface**: the upper surface, or back, of an organism.
Drone (drōn): the male bee.
Ductless gland: a gland that pours its secretion directly into the blood or lymph; same as *endocrine gland.*
Duodenum (dū'ō-dē'n*ŭ*m): the part of the small intestine nearest the stomach.
Dysentery (dĭs'*ĕ*n-tĕr'ĭ): a disease or inflammation of the large intestines interfering with the normal routine of evacuation.

Echinoderms (ē-kī'nō-dûrmz): a phylum of simple marine animals with spiny-skinned bodies, such as the starfish.
Ecology (ē-kŏl'ō-jĭ): a study of the relation of organisms to their environment.
Ectoderm (ěk'tō-dûrm): the outer cellular membrane that envelops a multicellular animal.
Efferent neurons (ěf'ẽr-*ĕ*nt nū'rŏnz): neurons that carry impulses from the brain and spinal cord to the muscles and other organs of the body; same as *motor neurons.*

Egg: female sex cell; same as *ovum* or *female gamete*.

Element: the smallest unit into which a substance may be divided chemically.

Embryo (ĕm′brĭ-ō): the new organism that develops from the union of a male and a female gamete.

Embryology (ĕm′brĭ-ŏl′ō-jĭ): the study of the processes involved in the growth of an organism from fertilization to birth.

End products of digestion: food converted by the action of digestive juices into substances that can be absorbed and used by the body.

Endocrine (ĕn′dō-krīn) **gland**: a gland that pours its secretion directly into the blood or lymph; same as ductless gland.

Endoderm (ĕn′dō-dûrm): the inner cellular membrane that envelops a multicellular animal.

Endosperm (ĕn′dō-spûrm): the tissue that provides nourishment for a developing embryo of seed plants.

Entomology (ĕn′tō-mŏl′ō-jĭ): the study of insects.

Environment (ĕn-vī′rŭn-mĕnt): external factors, such as moisture, temperature, and food, that affect the growth of plants and animals.

Enzyme (ĕn′zīm): a ferment, such as amylase or pepsin, that aids in digestion.

Epicotyl (ĕp′ĭ-kŏt′ĭl): the portion of a plant embryo above the cotyledons.

Epidermis (ĕp′ĭ-dûr′mĭs): the outside layer of cells in plants or animals.

Epiglottis (ĕp′ĭ-glŏt′ĭs): the lid or covering of the glottis.

Epoch (ĕp′ŏk): a subdivision of geological history.

Equatorial plate stage: the stage in the mitosis of a plant cell in which spindle fibers develop from the opposite sides or poles of the nucleus and become attached to each chromosome.

Esophagus (ē-sŏf′ā-gŭs): the tube that extends from the back of the mouth to the stomach; same as the gullet.

Eugenics (ū-jĕn′ĭks): the science that deals with the improvement of the human race through the application of the various laws of heredity.

Euglena (ū-glē′nȧ): a group of simple fresh-water algae or protozoans.

Euthenics (ū-thĕn′ĭks): the science that deals with uplift of society through the improvement of the environment.

Excretion (ĕks-krē′shŭn): the process of throwing off waste matter.

Exoskeleton (ĕk′sō-skĕl′ē-tŭn): the hard shell-like skeleton of certain animals, such as in a turtle or clam.

Extensor (ĕks-tĕn′sẽr) **muscles**: muscles used to straighten the limbs.

Extinct (ĕks-tĭŋkt′): no longer found upon the earth.

Eyespot: a small spot of color in lower organisms thought to be sensitive to light.

Facet (făs′ĕt): the lens of one eye in a compound eye.

Fang: the long hollow tooth of a poisonous snake.

Fauna (fô′nȧ): animals of a given area, or fossil animals of a certain period of geological history.

Femur (fē′mẽr): the large bone in the upper leg.

Fermentation (fûr′mĕn-tā′shŭn): the chemical effervescent action in a substance, such as the souring of milk, caused by the presence of certain enzymes.

Fertilization (fûr′tĭ-lĭ-zā′shŭn): the union of sperm cell and egg cell in the process of reproduction.

Fibrin (fī′brĭn): a fibrous protein in the blood that causes it to clot upon exposure to the air.

Fibula (fĭb′ū-lȧ): the smaller of the two bones in the lower leg.

Filial generation (F_1, F_2): the first and second generations of hybrid offspring following the crossing of individuals with unlike characters.

Filtrate (fĭl′trāt): the part of a liquid that passes through a filter.

Filterable virus (vī′rŭs): a form of life evident as the cause of disease

and yet too small to be detected by a microscope or entrapped by a filter.

Fission (fĭsh′ŭn): the division of a cell or body into two equal parts.

Flagellum (flȧ-jĕl′ŭm): a long threadlike appendage on a cell used for locomotion.

Flexor (flĕk′sẽr) **muscles**: muscles used to bend the limbs.

Flora (flō′rȧ): plants of a certain area; fossil plants of a given period of geological time.

Fossil (fŏs′ĭl): the original structure or trace of an organism preserved in the earth's crust.

Frond (frŏnd): the leaf of a fern.

Fumigation (fū′mĭ-gā′shŭn): the process of disinfecting by the use of poisonous fumes.

Function (fŭŋk′shŭn): the natural action of any part of a plant or animal.

Fungus (fŭn′gŭs; plural, **fungi**, fŭn′jī): a plant that has no chlorophyll, and therefore is dependent upon another organism for nourishment.

Gall (gôl): a growth on a plant caused by a parasite which lives within.

Gall bladder: a sac attached to the duct leading from the liver to the intestines, used for the storage of bile.

Gamete (găm′ēt): a mature sex cell, either male or female.

Gametophyte (gȧ-mē′tō-fīt): the sexual generation in alternation of generations; also the structure that bears sex cells.

Ganglion (găŋ′glĭ-ŏn; plural, **ganglia**, găŋ′glĭ-ȧ): a mass of nerve cells.

Gastric (găs′trĭk) **glands**: glands in the wall of the stomach that secrete the gastric juice.

Gastrula (găs′trōō-lȧ): the stage when a developing embryo is enveloped in a double-layered sac.

Gene (jēn): a particle in the chromosome that transmits a certain hereditary character.

Genetics (jē-nĕt′ĭks): a study of heredity and variations in the forms of plants and animals.

Genus (jē′nŭs; plural, **genera**, jĕn′ẽr-ȧ): a group in the classification of plants or animals between the family and the species.

Geology (jē-ŏl′ō-jĭ): a study of the structure and history of the earth's crust.

Geotropism (jē-ŏt′rō-pĭz′m): the reaction of plants to the force of gravity, as the growth of roots downward.

Germ: the common term for any microörganism, but especially for a bacterium.

Germicide (jûr′mĭ-sīd): any substance used to kill disease germs.

Germination (jûr′mĭ-nā′shŭn): the beginning of growth, especially from a seed or spore.

Gestation (jĕs-tā′shŭn) **period**: the time required for the development of an embryo.

Gills (gĭlz): respiratory organs of fish and other aquatic animals.

Gland (glănd): an organ which secretes a substance used in the body or thrown off as waste.

Glycogen (glī′kō-jĕn): a carbohydrate or animal starch stored in the liver.

Growth: the process of making more protoplasm than is needed for the production of heat, energy, and the repair of cells.

Guard cells: cells around the stomata which regulate the passage of gases into and out of a leaf.

Gullet (gŭl′ĕt): the tube that extends from the back of the mouth to the stomach; same as the esophagus.

Gymnosperms (jĭm′nō-spûrmz): plants with naked seeds, that is, not inclosed in ovaries; a subphylum of spermatophytes.

Habitat (hăb′ĭ-tăt): the place where an organism naturally lives.

Haemoglobin (hē′mō-glō′bĭn): the coloring matter of red corpuscles.

Herbaceous (hẽr-bā′shŭs) **plants**: plants without woody stems.

Herbivorous (hẽr-bĭv'ō-rŭs) **animal**: an animal that lives on plants.

Heredity (hē-rĕd'ĭ-tĭ): the transmission of characters from parent to offspring.

Hilum (hī'lŭm): a scar on a seed showing the point at which it was attached to the stalk.

Hormone (hôr'mōn): a substance secreted by ductless glands and other organs of the body that stimulates certain activities.

Host (hōst): a plant or animal that provides the food for a parasite.

Humerus (hū'mẽr-ŭs): the bone in the upper part of the arm.

Hybrid (hī-brĭd): the offspring that results from the mating of individuals with different characters.

Hydrogen (hī'drō-jĕn): an extremely light gaseous element found in water and many foods.
found in water and many foods.

Hydrotropism (hī-drŏt'rō-pĭz'm): the reaction of a plant to water.

Hygiene (hī'jĭ-ēn): the science that deals with the preservation and improvement of health.

Hyphae (hī'fē): threadlike filaments that compose the structure of a fungus plant.

Hypocotyl (hī'pō-kŏt'ĭl): the portion of a plant embryo below the cotyledons.

Imbibition (ĭm'bĭ-bĭsh'ŭn): the process by which a part of an organism, such as a root hair, absorbs moisture.

Immunity (ĭ-mū'nĭ-tĭ): the power to resist disease.

Imperfect flower: a flower that lacks either stamens or pistils.

Impulse: the tendency to act as a result of stimulation.

Incisors (ĭn-sī'zẽrz): the four front teeth, both above and below, used for cutting and biting.

Incomplete metamorphosis (mĕt'ȧ-môr'fō-sĭs): the slight modifications that take place during the development of young that possess the same general characteristics as the parents.

Incubation (ĭn'kū-bā'shŭn): the process of heating eggs to bring about development of the embryo.

Infection (ĭn-fĕk'shŭn): contamination by disease-producing organisms such as bacteria or Protozoa.

Inheritance (ĭn-hĕr'ĭ-tăns): the process by which characters are transmitted from parents to offspring.

Inoculation (ĭn-ŏk'ū-lā'shŭn): the injection of bacteria or a virus into the body for the purpose of producing a mild form of a disease.

Inorganic (ĭn'ôr-găn'ĭk) **substances**: materials formed by other than living processes.

Insectivorous (ĭn'sĕk-tĭv'ō-rŭs) **animal**: an animal that feeds upon insects.

Insoluble (ĭn-sŏl'ū-b'l) **substance**: a substance that will not dissolve in a liquid.

Instinct (ĭn'stĭŋkt): the tendency to act in a certain way without training.

Insulin (ĭn'sū-lĭn): a hormone produced in the pancreas; also a remedy containing the hormone used to control diabetes.

Intercellular cement: an invisible substance between the cells of an organism which holds them together.

Interdependence (ĭn'tẽr-dē-pĕn'dĕns): dependence of two organisms upon each other.

Invertebrates (ĭn-vûr'tē-brāts): animals that have no backbone.

Iris (ī'rĭs): the colored membrane that surrounds the pupil of the eye.

Iris diaphragm (dī'ȧ-frăm): the part of a compound microscope which regulates the amount of light admitted to the object.

Irritability (ĭr'ĭ-tȧ-bĭl'ĭ-tĭ): the tendency to react to stimuli.

Kidney (kĭd'nĭ): an organ in the body that filters waste products from blood, chiefly water and urea.

Labium (lā'bĭ-ŭm): the lower lip of a biting insect.

Labrum (lā′brŭm): the upper lip of a biting insect.
Lacteals (lăk′tē-ălz): the absorbing parts of the lymphatic system.
Larva (lär′vȧ): the stage between the egg and adult in the metamorphosis of certain animals during which they feed, grow, and move about.
Larynx (lăr′ĭŋks): the thickened cartilage at the upper end of the windpipe.
Legume (lĕg′ūm): a family of plants including the pea and bean; also the seed pod or fruit of such plants.
Lens (lĕnz): a piece of glass or other substance with two opposite regular surfaces, at least one of which is curved; also the crystalline lens of the eye.
Lenticel (lĕn′tĭ-sĕl): an opening in the stem of woody plants through which air passes.
Lepidoptera (lĕp′ĭ-dŏp′tẽr-ȧ): an order of insects consisting of butterflies and moths.
Leprosy (lĕp′rō-sĭ): a very contagious disease resulting in a sloughing off of the skin, nerves, and mucous membranes.
Lichen (lī′kĕn): a plant composed of an alga and a fungus.
Life zone. *See* Zone, first meaning.
Ligament (lĭg′ȧ-mĕnt): a band of inelastic tissue that holds joints together and organs in place.
Lipase (lĭp′ās): an enzyme that breaks down fats into fatty acids and glycerin.
Lymph (lĭmf): blood plasma and white blood corpuscles that surround the cells; also the contents of the lymphatic system.
Lysin (lī′sĭn): an antibody that dissolves bacteria.

Maggot (măg′ŏt): the wormlike larva of a fly.
Malaria (mȧ-lâr′ĭ-ȧ): a disease caused by the bite of the female Anopheles mosquito, which injects the germ *Plasmodium malariae.*
Mammal (măm′ăl): a vertebrate that feeds its young on milk secreted by mammary glands.
Mandibles (măn′dĭ-b′lz): upper jaws of a biting insect.
Mantle (măn′t′l): a soft fold in the body wall of a mollusk that secretes the shell.
Marine (mȧ-rēn′) **life**: life occurring in the ocean or on its shores.
Mastication (măs-tĭ-kā′shŭn): the chewing of food.
Maxillae (măk-sĭl′ē): lower jaws of a biting insect.
Maxillipeds (măk-sĭl′ĭ-pĕdz): toothed appendages or jaws that extend from the thorax of crustaceans.
Medulla oblongata (mē-dŭl′ȧ ŏb′-lŏng-gā′tȧ): the lowest part of the brain or the part next to the spinal cord.
Medullary (mĕd′ŭ-lĕr′ĭ) **rays**: tissues that radiate from the center of woody stems carrying food and water.
Megaspore (mĕg′ȧ-spōr): a cell in the ovule of a flowering plant from which the female gametophyte develops.
Membrane (mĕm′brān): a thin, sheet-like structure connecting other structures or serving to cover or line some part of an organ.
Mesoderm (mĕs′ō-dûrm): the middle layer of cells in an animal embryo.
Metabolism (mē-tăb′ō-lĭz′m): the sum total of the processes concerned in the building up and tearing down of protoplasm.
Metamorphosis (mĕt′ȧ-mōr′fō-sĭs): changes that alter the form and structure of an animal as it passes from the egg stage to the adult.
Microbe (mī′krōb): any microörganism; usually refers to a bacterium that causes disease.
Micropyle (mī′krō-pīl): a tiny opening in the ovule of a plant through which the pollen passes on its way to the egg in the female gametophyte.
Microscope (mī′krō-skōp): an instrument in which a combination of lenses, mounted in relation to one another, form an enlarged image of the object under observation.

Millepede (mĭl'ĭ-pēd): a small arthropod with many legs, usually two pair to each segment, and small antennae.

Mimicry (mĭm'ĭk-rĭ): the resemblance, for protection, of one organism to another or to its environment.

Mitosis (mĭ-tō'sĭs): a complex method of cell division in which the chromatin material is separated into two equal parts.

Molecule (mŏl'ė-kūl): the smallest particle of a substance that retains the identity of the substance.

Mollusks (mŏl'ŭskz): a phylum of animals with soft bodies, usually inclosed in shells.

Molting (mōlt'ĭng): the shedding of hair, feathers, outer layer of skin, and similar parts of the body.

Monocotyledon (mŏn'ō-kŏt'ĭ-lē'-dŭn): a plant in which the embryo has only one cotyledon.

Morphology (môr-fŏl'ō-jĭ): a study of the forms and structures of organisms.

Morula (mŏr'ōō-lȧ): a globular mass of cells formed during the cleavage of an egg.

Motor neurons. *See* Efferent neurons.

Mucous (mū'kŭs) **membrane:** a moist membrane that lines all passages opening into the body and cavities within the body itself.

Mucus (mū'kŭs): a thick slippery liquid secreted by mucous membrane.

Muscle (mŭs''l): an organ or tissue that produces motion.

Mutant (mū'tănt): an individual possessing one or more characters that are markedly different from those of its parents.

Mycelium (mī-sē'lĭ-ŭm): the mass of hyphae in a fungus plant.

Myriapods (mĭr'ĭ-ȧ-pŏdz'): a class of arthropods that includes centipedes and similar animals.

Naviculae (nȧ-vĭk'ū-lē): groups of free swimming diatoms so named because of their boatlike shapes.

Natural selection: the struggle for existence, in which only the fittest survive to propagate the species.

Nerve (nẽrv): a number of parallel axons bound together and protected by a sheath.

Neuron (nū'rŏn): a nerve cell including its branches—axon and dendrites.

Nitrate (nī'trāt): a chemical compound that contains nitrogen.

Nitrogen (nī'trō-jĕn): a gas making up almost four-fifths of the air and entering into many compounds in the bodies of plants and animals.

Nitrogen-fixing bacteria: bacteria that live in the roots of legumes or in the soil and transform nitrogen from the air into nitrates for the use of plants.

Node (nōd): the place from which a leaf arises on a stem.

Nonpathogenic (nŏn'păth'ō-jĕn'ĭk) **bacteria:** bacteria that are nonpoisonous or helpful.

Notochord (nō'tō-kôrd): a rod of elastic tissue near the dorsal surface of the body in the lower vertebrates.

Nucleolus (nū-klē'ō-lŭs): a globular body found in many cells, the exact function of which is unknown.

Nucleus (nū'klė-ŭs): the denser part of the protoplasm in a cell, usually near the center.

Nutrient (nū'trĭ-ĕnt): a nourishing substance obtained from foods.

Ocelli (ō-sĕl'ī): the three simple eyes of an insect.

Olfactory (ŏl-făk'tō-rĭ) **nerve:** the nerve that carries odor stimuli from the nostrils to the brain.

Ommatidium (ŏm'ȧ-tĭd'ĭ-ŭm): one of the small eyes of the compound eye of an insect.

Omnivorous (ŏm-nĭv'ō-rŭs) **animals:** animals that feed on both plants and animals.

Oögonium (ō'ō-gō'nĭ-ŭm): the female sex organ of certain thallophytes.

Operculum (ō-pûr-kū-lŭm): the flap that covers the gills of fish.

Ophthalmia (ŏf-thăl′mĭ-*ȧ*): an inflammation of the eye.
Opsonin (ŏp′sṓ-nĭn): an antibody that prepares bacteria so that they will be more readily digested or devoured by the phagocytes.
Optic nerve: the nerve that carries light stimuli from the eye to the brain.
Organ: a group of tissues that carry on a definite work.
Organic (ôr-găn′ĭk) **matter:** any substance derived from living organisms.
Organism (ôr′g*ă*n-ĭz′m): any living animal or plant.
Ornithology (ôr-nĭ-thŏl′ṓ-jĭ): the study of birds.
Orthoptera (ŏr-thŏp′tẽr-*ȧ*): an order of insects that includes the grasshopper, cricket, and cockroach.
Osculum (ŏs′kū-l*ŭ*m): the large opening in a sponge.
Osmosis (ŏs-mō′sĭs): the diffusion of a liquid through a semipermeable membrane.
Ovary (ō′vâ-rĭ): the organ of a plant or animal which produces eggs.
Oviduct (ō′vĭ-dŭkt): the duct that leads from the ovary to the vagina.
Oviparous (ṓ-vĭp′*ȧ*-r*ŭ*s) **animal:** an animal that produces eggs from which the young are hatched outside the body.
Ovipositor (ō′vĭ-pŏs′ĭ-tẽr): an organ at the end of the abdomen of a female insect used for drilling a hole and depositing eggs.
Ovule (ō′vūl): the structure within a plant ovary which contains an egg and later develops into a seed.
Oxidation (ŏk′sĭ-dā′sh*ŭ*n): the chemical combination of oxygen with other substances.
Oxygen (ŏk′sĭ-j*ĕ*n): a colorless, gaseous element found in air, soil, and water and essential to life.

Paleontology (pā-lḗ-ŏn-tŏl′ṓ-jĭ): the study of plants and animals of the past through fossils in the rocks.
Palisade (păl′ĭ-sād′) **cells:** long cells beneath the upper epidermis of a leaf.
Palmate (păl′māt): having lobes radiating from a common point.
Palpi (păl′pī): feelers on the lower jaw of an insect.
Pancreas (păn′krḗ-*ă*s): a gland that secretes the digestive juice called pancreatic juice.
Papillae (p*ȧ*-pĭl′ḗ): minute projections on various parts of the body, such as the skin or tongue.
Paramecium (păr′*ȧ*-mē′shĭ-*ŭ*m): a small slipper-shaped one-celled animal found in ponds.
Parasite (păr′*ȧ*-sīt): an organism that lives at the expense of another living organism.
Parthenogenesis (pär′thḗ-nṓ-jĕn′ḗ-sĭs): the process of reproduction from a nonfertilized egg.
Pasteurization (păs′tẽr-ĭ-zā′sh*ŭ*n): the process of heating milk or other fluids to a temperature of 55° to 70° Centigrade for the purpose of killing bacteria or of rendering them harmless.
Pathogenic (păth′ṓ-jĕn′ĭk) **bacteria:** those that cause disease.
Pathology (p*ȧ*-thol′ṓ-jĭ): the study of diseases.
Pectoral (pĕk′tṓ-r*ă*l) **girdle:** the part of the skeleton of a vertebrate to which the anterior or pectoral appendages are attached.
Pellagra (p*ĕ*-lăg′r*ȧ*): a disease of the skin, digestive tract, and nerves which is caused by lack of certain vitamins.
Pelvic (pĕl′vĭk) **girdle:** the part of the skeleton of a vertebrate to which the hind legs are attached.
Pepsin (pĕp′sĭn): an enzyme of the gastric juice which acts upon proteins.
Peptone (pĕp′tōn): one of the soluble forms that result from the action of gastric juice upon proteins.
Pericardium (pĕr′ĭ-kär′dĭ-*ŭ*m): the membrane that surrounds the heart.
Peristalsis (pĕr′ĭ-stăl′sĭs): the wavelike muscular action or churning of the stomach.
Petal (pĕt′*ă*l): an inner leaf of a flower; part of the corolla.
Petiole (pĕt′ĭ-ōl): the stalk of a leaf.

Phagocyte (făg'ô-sīt): a white corpuscle that helps to rid the body of bacteria and dangerous wastes.

Pharynx (făr'ĭnks): the part of the food tract between the mouth and the esophagus.

Phlegm (flĕm): a mucous secretion of the respiratory tract.

Phloem (flō'ĕm): the outer portion of a vascular bundle which transports saps.

Photosynthesis (fō'tô-sĭn'thê-sĭs): the process of food building that takes place within cells of a green plant in the presence of sunlight.

Phototropism (fô-tŏt'rô-pĭz'm): the reaction of an organism to light.

Phylum (fī'lŭm; plural, **phyla**, fī'lȧ): a main subdivision of the plant or animal kingdom.

Physiology (fĭz'ĭ-ŏl'ô-jĭ): the study of the functions of living organisms.

Pistil (pĭs't'l): the part of a flower that contains the ovule.

Pith (pĭth): the tissue of thin-walled cells in the center of the stem of a dicotyledonous plant.

Pituitary (pĭ-tū'ĭ-tĕr'ĭ): a ductless gland situated at the base of the brain.

Placenta (plȧ-sĕn'tȧ): in mammals, the part of the chorion membrane through which the young secure nourishment and oxygen before birth; in plants, the part of the ovary wall to which the ovules are attached.

Plankton (plăngk'tŏn): microscopic plant and animal organisms that live in water.

Plasma (plăz'mȧ): the fluid content of the blood.

Plastid (plăs'tĭd): a specialized unit of protoplasm.

Pleura (plo͝or'ȧ): the membrane that surrounds the lungs and lines the cavity in which they are situated.

Plumule. *See* Epicotyl.

Pollen (pŏl'ĕn) **grain:** the yellow spore of a seed-bearing plant in which the male gamete develops.

Pollination (pŏl'ĭ-nā'shŭn): the transfer of pollen from an anther to a stigma.

Polyp (pŏl'ĭp): one of the forms of a coelenterate, such as the sea anemone, or one of the members of a coral colony.

Porifera (pô-rĭf'ēr-ȧ): the class made up of the sponges.

Posterior (pŏs-tē̦r'ĭ-ēr): the rear part of an organism.

Precipitin (prê-sĭp'ĭ-tĭn): an antibody that removes bacteria and various protein substances from solution so that they are harmless.

Predaceous (prê-dā'shŭs) **animal:** an animal that lives by preying upon other animals.

Primates (prī-mā'tēz): the class of erect mammals.

Proboscis (prô-bŏs'ĭs; plural, **proboscides**, prô-bŏs'ĭ-dēz): a tubular prolongation of the head of an animal, such as the sucking tube of an insect or the trunk of an elephant.

Protective coloration: coloration in animals which enables them to blend into their surroundings.

Proteins (prō'tê-ĭnz): a class of foods made up principally of carbon, hydrogen, oxygen, and nitrogen.

Prothallium (prô-thăl'ĭ-ŭm): a small plant that represents the sexual generation of a fern.

Protonema (prō'tô-nē'mȧ): a filament in mosses, formed by the germination of an asexual spore, which produces a sexual plant.

Protoplasm (prō'tô-plăz'm): the living matter of cells.

Protozoa (prō'tô-zō'ȧ): the phylum of one-celled animals.

Pseudopodium (sū'dô-pō'dĭ-ŭm): a protoplasmic projection in Protozoa used for locomotion.

Pteridophytes (tĕr'ĭ-dô-fīts'): the phylum of plants that includes the ferns and horsetails.

Ptyalin (tī'ȧ-lĭn): a digestive enzyme in the saliva which acts upon starch.

Pulmonary (pŭl'mô-nâ-rĭ) **artery:** the artery that carries impure blood from the heart to the lungs.

Pulmonary vein: the vein that carries the pure blood from the lungs to the heart.

Pulvinus (pŭl-vī'nŭs): an enlargement at the point of attachment of a leaf or leaflet.
Pupa (pū'pȧ): the stage between the larva and the adult in the metamorphosis of an insect in which the creature is dormant.
Pyloric (pī-lŏr'ĭk): the end of the stomach which connects with the small intestine.

Quadruped (kwŏd'rōō-pĕd): a four-footed animal.

Range (rānj): the area in which any given species lives and moves.
Realm (rĕlm): a very large area bounded by more or less impassable barriers which prevent life forms from passing in or out.
Recapitulation (rē'kȧ-pĭt'ū-lā'shŭn): the stages in the development of an embryo in which certain structures resemble those of earlier forms of life.
Recessive (rē-sĕs'ĭv) **character**: a character that does not appear in the hybrid generation but is capable of being passed on to descendants.
Reef (rēf): a narrow ridge of sand, rocks, or coral in the sea.
Reflex (rē'flĕks) **action**: a simple response not the result of thought.
Regeneration (rē-jĕn'ēr-ā'shŭn): the process by which lost parts of plants and animals are replaced.
Region (rē'jŭn): the area over which the habitats of an organism are distributed.
Reproduction (rē-prō-dŭk'shŭn): the process by which an organism produces offspring.
Respiration (rĕs'pĭ-rā'shŭn): the taking in of oxygen and giving off of carbon dioxide.
Retina (rĕt'ĭ-nȧ): the inner coat at the back of the eye, which is sensitive to light.
Rhizome (rī'zōm): a stem that grows in the ground like a root.
Rhizoid (rī'zoid): a rootlike hair on fungus and other lower forms of plants.
Rickets (rĭk'ĕts): a disease of the bones caused by lack of certain vitamins in the food.
Root hair: a threadlike growth on a root.
Rotifers (rō'tĭ-fẽrz): one of the main classifications of the animal kingdom; wheelworms.
Rudimentary (rōō'dĭ-mĕn'tȧ-rĭ): early or primitive.
Ruminant (rōō'mĭ-nănt): an even-toed hoofed animal that chews a cud.
Rust (rŭst): a plant disease caused by certain fungi.

Saliva (sȧ-lī'vȧ): the digestive juice of the mouth secreted by the salivary glands.
Sanitation (săn'ĭ-tā'shŭn): the work of providing and maintaining a healthful environment.
Saprophyte (săp'rō-fīt): a plant that lives on dead organic matter.
Sargasso (sär-găs'ō) **Sea**: a large tract of comparatively still water in the North Atlantic Ocean in which there is a great mass of floating seaweed.
Savanna (sȧ-văn'ȧ): a tropical or subtropical grassland.
Scapula (skăp'ū-lȧ): the shoulder blade.
Scavenger (skăv'ĕn-jẽr): an animal that eats decaying matter or refuse.
Schick (shĭk) **test**: a test to determine whether a person is immune to diphtheria.
Scion (sī'ŭn): a bud, shoot, or branch of one plant grafted upon another.
Secretion (sē-krē'shŭn): a fluid produced by glands, such as the pancreatic juice by the pancreas.
Seed (sēd): a ripened ovule with its embryo.
Segment (sĕg'mĕnt): a division in the bodies of certain lower animals, such as worms.
Self-pollination: transfer of pollen from the anther to the stigma of the same flower.
Sensation: the feeling produced by the stimulation of a sense organ.

Sense organ: an organ, such as the eye or ear, which receives stimuli resulting in a special sensation.
Sensory neurons. *See* Afferent neurons.
Sepals (sē′pălz): the outermost leaf-like parts of a flower; part of the calyx.
Serum (sē′rŭm): the liquid part of blood plasma; also a substance injected into the blood stream for the prevention or treatment of certain diseases.
Seta (sē′tȧ): the supporting stem of the spore case in moss plants; a bristle-like organ of lower animals.
Sexual (sěks′ū-ăl) **reproduction:** reproduction by a union of sperm and egg.
Shoot: a young plant or new twig, including stem and leaves.
Shrub (shrŭb): a small, woody plant, usually with several stems or branches.
Skeleton (skěl′ē-tŭn): the bony part of an animal's body to which the muscles are attached.
Smut (smŭt): a parasitic fungus, often recognized by its black spongy appearance.
Soluble (sŏl′ū-b′l) **substance**: a substance that will dissolve in a liquid.
Sori (sō′rī): little brown spots on the underside of a fern leaf which contain the spore cases.
Spawn (spôn): *noun*—the eggs of fishes, frogs, clams, and other water animals; *verb* applying to water animals—to lay eggs.
Species (spē′shēz): a group of plants or animals that have the same or nearly the same characters; a division of a genus.
Sperm (spûrm) **cell:** a male sex cell or gamete.
Spermatophytes (spûr′mȧ-tō-fīts′): the phylum that includes the seed plants.
Spinal (spī′năl) **cord:** a bundle of nervous tissue that extends from the brain through a canal in the spinal column.
Spiracles ((spĭr′ȧ-k′lz): openings in the bodies of insects which are used in breathing.
Spirem (spī′rēm): a network of chromatin and linin which forms during the mitosis of a plant cell.
Spirillum (spī-rĭl′ŭm; plural, **spirilla,** spī-rĭl′ȧ): a spiral-shaped bacterium.
Spleen (splēn): a ductless, gland-like organ at the left of the stomach.
Sporangium (spō-răn′jĭ-ŭm; plural, **sporangia,** spō-răn′jĭ-ȧ): the spore case of plants that reproduce by spores.
Spore (spōr): an asexual reproductive cell.
Sporophyte (spō′rō-fīt): a plant that produces asexual spores.
Sport. *See* Mutant.
Stagnant (stăg′nănt) **water:** water, such as that in a pond, which has become stagnant.
Stamen (stā′měn): the organ of a flower that produces pollen.
Staminate (stăm′ĭ-nāt): having stamens but no pistils, as the cone of conifers.
Sterile (stěr′ĭl): pure.
Sternum (stûr′nŭm): the breastbone.
Stigma (stĭg′mȧ): the part of the pistil of a flower that receives the pollen.
Stimulus (stĭm′ū-lŭs): any agent that excites the tissues of a plant or animal, or brings about action.
Stipules (stĭp′ūlz): paired leaflike structures found at the base of a petiole.
Stock (stŏk): the root or stem to which a part is grafted.
Stolon (stō′lŏn): a branch arising near the base of a plant, from which new plants develop.
Stoma (stō′mȧ; plural, **stomata,** stō′mȧ-tȧ): a mouthlike opening in the epidermis of a plant; sometimes called a "breathing pore."
Strata (strā′tȧ): layers of substance, as rock.
Streptococcus (strěp′tō-kŏk′ŭs): a germ or bacterium that produces serious infection, usually of the nose, throat, and lungs.
Style (stīl): the part of the pistil between the stigma and the ovary.

Swimmerets (swĭm'ẽr-ĕts): appendages on the abdomens of crustaceans used both in swimming and in reproduction.

Symbiosis (sĭm'bĭ-ō'sĭs): a partnership of two or more dissimilar organisms.

Symmetry (sĭm'ē-trĭ): the balanced arrangement of parts.

Synapse (sĭ-năps'): the point at which a nervous impulse passes from the axon of one neuron to the dendrites of another.

Systemic (sĭs-tĕm'ĭk) **circulation:** the flow of blood to all parts of the body.

Tarsal (tär'săl): an ankle bone.

Taxonomy (tăks-ŏn'ō-mĭ): the naming and classification of organisms according to ancestral relationship.

Tendon (tĕn'dŭn): an inelastic bundle of tissue that connects a muscle with a bone or another muscle.

Tendril (tĕn'drĭl): a threadlike twisting growth which enables a plant to climb by attaching itself to another plant or near-by object.

Tentacles (tĕn'tȧ-k'lz): long flexible processes at the anterior end of certain invertebrates, used as sense organs and as arms for grasping.

Testa (tĕs'tȧ): the hard outer coat of a seed.

Testes (tĕs'tēz): sperm-producing organs.

Thallophytes (thăl'ō-fīts): the phylum that includes the simplest forms of plants with no true stem or leaves.

Thermotropism (thẽr-mŏt'rō-pĭz'm): the reaction of an organism to heat.

Thigmotropism (thĭg-mŏt'rō-pĭz'm): the reaction of an organism to contact.

Thoracic duct: the largest tube of the lymphatic system.

Thorax (thō'răks): the part of the body between the head and the abdomen of an insect.

Thyroid (thī'roid) **gland:** a ductless gland situated in the neck.

Tissue (tĭsh'ū): a group of cells alike in size, shape, and function.

Toxin (tŏk'sĭn): a poison secreted by disease-producing germs.

Trachea (trā'kē-ȧ; plural, **tracheae,** trā'kē-ē): in vertebrates the air tube, or windpipe, that leads to the lungs; in insects, one of the air tubes.

Trachoma (trȧ-kō'mȧ): a disease of the conjunctiva of the eye, often resulting in blindness.

Transition (trăn-zĭsh'ŭn) **zone:** the area at the edges of two adjoining zones which contains the flora and fauna of both zones.

Transpiration (trăns'pĭ-rā'shŭn): the loss of water vapor from the exposed surface of plants.

Tropism (trō'pĭz'm): the reaction of plants and lower forms of animal life to such stimuli as heat, light, and gravity.

Trypsin (trĭp'sĭn): an enzyme secreted by the pancreas which acts on protein matter.

Tuber (tū'bẽr): the enlarged part of an underground stem.

Tubercle (tū'bẽr-k'l): a small, round growth on a plant or animal, as on the roots of legumes.

Tuberculin (tū-bûr'kū-lĭn) **test:** a test to show the presence of active or dormant tuberculosis germs.

Tuberculosis (tū-bûr'kū-lō'sĭs): an infectious disease caused by the tubercle bacillus.

Turgor (tûr'gŏr): normal rigidity or stiffness of living plant cells due to the pressure of water within the cell walls.

Turgidity (tûr-jĭd'ĭ-tĭ): the swelling of the entire plant or animal or one of its parts.

Tympanic (tĭm-păn'ĭk) **membrane:** a membrane that stretches across the inner end of the auditory canal; same as eardrum.

Ulna (ŭl'nȧ): one of the two bones of the lower arm.

Umbilical (ŭm-bĭl'ĭ-kăl) **cord:** the connection between mother and embryo through which the embryo receives nourishment.

Unit character: a quality, such as height, size, or color, inherited independently of other characters.
Urea (ū-rē'*ȧ*): a nitrogenous waste product in the body.

Vaccinate (văk'sĭ-nāt): to inoculate with a vaccine to prevent disease.
Vaccine (văk'sĭn): a substance containing living or dead pathogenic organisms or a virus, used in inoculation for the prevention of disease.
Vacuole (văk'ū-ōl): a space within a cell which contains air, food, water, or waste material.
Vallisneria (văl'ĭs-nē'rĭ-*ȧ*): a genus of submerged aquatic plants; same as wild celery.
Variation (vā'rĭ-ā'sh*ŭ*n): the occurrence of differences between organisms of the same species.
Variety (v*ȧ*-rī'ĕ-tĭ): a subdivision of a plant or animal species based upon minor differences in their characters.
Vascular (văs'kū-l*ȧ*r) **bundle:** bundle of tissue in a plant which transports food materials.
Vegetative reproduction: the process by which a new organism develops from a part of the body of another organism.
Vein (vān): in plants, the vascular bundle of a leaf; in animals, a vessel for carrying blood.
Vena cava (vē'n*ȧ* kā'v*ȧ*) **superior:** the vein in air-breathing vertebrates which returns the impure blood to the right auricle of the heart.
Venation (vē-nā'sh*ŭ*n): the arrangement of veins in a leaf or in the wings of an insect.
Ventral (vĕn'tr*ă*l): the abdominal or lower side of an organism.
Ventricle (vĕn'trĭ-k'l): the chamber of the heart which receives blood from an auricle and delivers it to the arteries.
Vertebra (vûr'tē-br*ȧ*; plural, **vertebrae,** vûr'tē-brē): one of the small bones which make up the backbone or spinal column.
Vertebrates (vûr'tē-brāts): a subphylum of the chordates which is characterized by the possession of a spinal column.
Vestigial (vĕs-tĭj'ĭ-*ă*l): pertaining to a remnant of an organ.
Villi (vĭl'ī; singular, **villus,** vĭl'*ŭ*s): small projections on the wall of the small intestine which carry on absorption.
Virus (vī'r*ŭ*s): the poison of an infectious disease.
Vitamin (vī't*ȧ*-mĭn): a substance in food which is essential to growth, nutrition, and prevention of disease.
Vitreous humor (vĭt'rē-*ŭ*s hū'mẽr): the fluid part of the eyeball.
Voluntary (vŏl'*ŭ*n-tĕr'ĭ) **muscle:** a muscle under the control of the will.
Volvox (vŏl'vŏks): an organism in which certain cells are set apart for reproduction.

Widal (vē'däl) **test:** a test to determine whether a person has typhoid fever.

X-ray: a ray stronger than ordinary light used in examining the interior of the body.
Xylem (zī'lĕm): the woody tissue in a plant.

Yeast (yēst): a single-celled fungus plant which causes fermentation.
Yolk sac: the membrane surrounding the yolk of an egg.
Yellow fever: a tropical disease spread by the bite of the Aëdes mosquito.

Zone: an area in which the geographic and climatic conditions are fairly uniform, thus providing a favorable environment for certain forms of life; in water, also location near or away from shore or at different depths, where certain life forms are found.
Zoölogy (zō-ŏl'ō-jĭ): the study of animal life.
Zygote (zī'gōt): a cell formed by the union of two gametes.

INDEX